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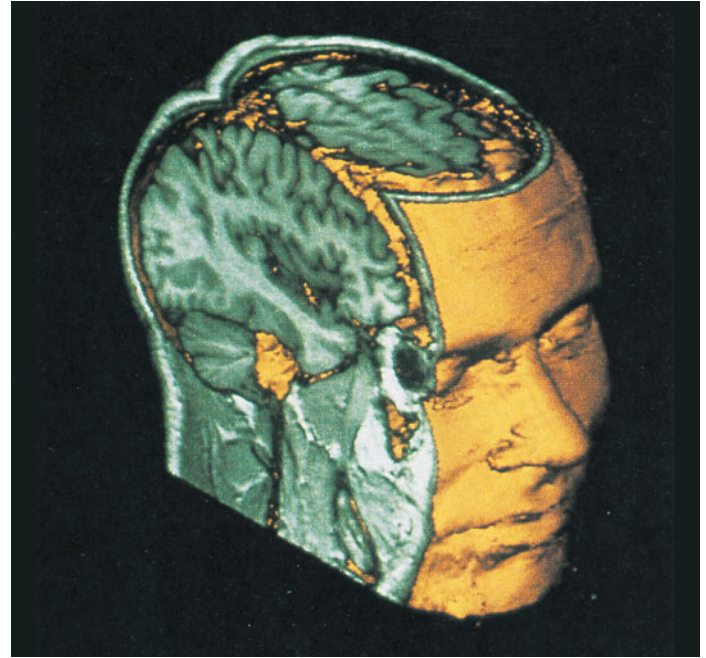
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(a) MRI of the head; sagittal section, artificially colored



(b) Volume rendering of an MRI of the head

FIGURE 1.15 Magnetic resonance image (MRI). The flat surfaces in (b) show the original MRI data.

ful in trauma situations. MRI is also more sensitive to patient movement during the scan, and it does not visualize bone or other tissues with low water content.

In conclusion, the images formed by computerized imaging techniques can be quite stunning. Keep in mind, however, that the images are abstractions assembled within a computer. They are artificially enhanced for sharpness and artificially colored to increase contrast or to highlight areas of interest. Although computer-based images are not inaccurate, they are several steps removed from direct visual observation.

check your understanding

10. What imaging technique is best suited for each of the clinical situations described? (a) Examining gallbladder for possible gallstones in response to a patient's complaints of sharp pain in the right hypochondriac region of the abdomen; (b) ruling out a broken bone in a patient complaining of wrist and forearm pain; (c) examining of the knee of a patient complaining of persistent pain following an injury on the athletic field; (d) assessing possible damage to abdominal viscera resulting from a car accident.

For answers, see Appendix B.

CHAPTER SUMMARY

An Overview of Anatomy (pp. 2–6)

1. Anatomy is the study of body structure. In this book, structures are considered in terms of their function.

Branches of Anatomy (p. 2)

2. Branches of anatomy include gross anatomy, microscopic anatomy (histology), and developmental anatomy.

Anatomical Terminology (p. 3)

3. Because most structures in the body have formal Greek and Latin names, learning the meaning of word roots will help you understand anatomy.

The Hierarchy of Structural Organization (pp. 3–6)

4. The levels of structural organization of the body, from simplest to most complex, are chemical, cellular, tissue, organ, organ system, and the human organism itself.
5. The organ systems in the body are the integumentary (skin), skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, immune, respiratory, digestive, urinary, and reproductive systems.

Scale: Length, Volume, and Weight (p. 6)

6. Important units of length measurement are meters (m) for the organism, centimeters (cm) for the organs, and micrometers (μm) for cells. For other units of size, see Appendix A.

Gross Anatomy: An Introduction (pp. 6–13)**Regional and Directional Terms (p. 6)**

7. In the adult anatomical position, the body stands erect, facing forward with legs together. The arms are at the sides, with the palms forward.
8. Regional terms are used to designate specific areas of the body (see Figure 1.3).
9. Directional terms allow anatomists to describe the location of body structures with precision. Important terms include superior/inferior; anterior/posterior (or ventral/dorsal); medial/lateral; proximal/distal; and superficial/deep (see Table 1.1).

Body Planes and Sections (pp. 6–7)

10. The body or its organs may be cut along planes to produce different types of sections. Frequently used are sagittal, frontal, and transverse planes.

The Human Body Plan (pp. 10–11)

11. The basic structures we share with all other vertebrate animals are the tube-within-a-tube body plan, bilateral symmetry, a dorsal hollow nerve cord, notochord and vertebrae, segmentation, and pharyngeal pouches.

Body Cavities and Membranes (pp. 11–12)

12. The body contains two major closed cavities: the dorsal cavity, subdivided into the cranial and vertebral cavities; and the ventral body cavity, subdivided into the thoracic and abdominopelvic cavities.
13. Within the ventral cavity are the visceral organs (such as the heart, lungs, intestines, and kidneys) and three serous cavities: pleural, pericardial, and peritoneal cavities. These slitlike cavities are lined by thin membranes, the parietal and visceral serosae (see Figure 1.7). The serosae produce a thin layer of lubricating fluid that decreases friction between moving organs.

Abdominal Regions and Quadrants (pp. 12–13)

14. To map the visceral organs in the abdominopelvic cavity, clinicians divide the abdomen into nine regions or four quadrants.

Microscopic Anatomy: An Introduction (pp. 14–15)**Light and Electron Microscopy (pp. 14–15)**

15. To illuminate cells and tissues, the light microscope (LM) uses light beams and the transmission electron microscope (TEM or EM) uses electron beams. EM produces sharper images than LM at higher magnification.
16. The preparation of tissues for microscopy involves preservation (fixation), sectioning, and staining. Stains for LM are colored dyes, whereas stains for TEM are heavy-metal salts.

Scanning Electron Microscopy (p. 15)

17. Scanning electron microscopy (SEM) provides sharp, three-dimensional images at high magnification.

Clinical Anatomy: An Introduction to Medical Imaging Techniques (pp. 15–19)**X-Ray Imaging (pp. 15–16)**

18. In conventional radiographs, X rays are used to produce negative images of internal body structures. Denser structures in the body appear lighter (whiter) on the X-ray film.

Advanced X-Ray Techniques (p. 16)

19. Computed tomography (CT) produces improved X-ray images that are taken in cross section to avoid overlapping images of adjacent organs and computer enhanced for clarity. Angiography produces sharp X-ray images of blood vessels injected with a contrast medium.

Positron Emission Tomography (PET) (pp. 16–18)

20. PET tracks radioisotopes in the body, locating areas of high energy consumption and high blood flow.

Sonography (p. 18)

21. Ultrasonography provides sonar images of developing fetuses and internal body structures.

Magnetic Resonance Imaging (pp. 18–19)

22. MRI subjects the body to strong magnetic fields and radio waves, producing high-contrast images of soft body structures.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. The correct sequence of levels forming the body's structural hierarchy is (a) organ, organ system, cellular, chemical, tissue; (b) chemical, tissue, cellular, organismal, organ, organ system; (c) chemical, cellular, tissue, organ, organ system, organismal; (d) organismal, organ system, organ, chemical, cellular, tissue.
2. Using what you learned about scale in this chapter, choose one of the values in Column B as an appropriate height or diameter for each object listed in Column A.

Column A

- _____ (1) white blood cell
- _____ (2) stomach
- _____ (3) professional basketball player

Column B

- (a) 2 m
- (b) 25 cm
- (c) 1 micrometer
- (d) 10 micrometers

3. Using the terms listed below, fill in the blank with the proper term.

anterior	superior	medial	proximal	superficial
posterior	inferior	lateral	distal	deep

- (a) The heart is located _____ to the diaphragm.
- (b) The muscles are _____ to the skin.
- (c) The shoulder is _____ to the elbow.
- (d) In anatomical position, the thumb is _____ to the index finger.
- (e) The vertebral region is _____ to the scapular region.
- (f) The gluteal region is located on the _____ surface of the body.
- (g) The hip bone is _____ to the navel.
- (h) The nose is _____ to the chin.
- (i) The toes are _____ to the heel.
- (j) The scalp is _____ to the skull.

4. Match each anatomical term for body regions listed in column B with the common name listed in column A.

Column A

- (1) armpit
- (2) buttocks
- (3) back
- (4) shoulder blade
- (5) front of elbow
- (6) hand
- (7) groin
- (8) forehead
- (9) lower back
- (10) sole of foot

Column B

- (a) inguinal
- (b) frontal
- (c) dorsal
- (d) axilla
- (e) lumbar
- (f) gluteal
- (g) antecubital
- (h) plantar
- (i) manus
- (j) scapular

5. Which of these organs would not be cut by a section through the midsagittal plane of the body? (Hint: See Figure 1.8) (a) urinary bladder, (b) gallbladder, (c) small intestine, (d) heart.
6. State whether each structure listed below is part of the inner tube (I) or outer tube (O).
- | | |
|---------------------------|-------------------------|
| — (1) intestines | — (5) abdominal muscles |
| — (2) lungs | — (6) esophagus |
| — (3) ribs | — (7) spinal cord |
| — (4) backbone (vertebra) | |
7. Indicate whether each of the following conditions or statements applies to the dorsal body cavity (D) or the ventral body cavity (V).
- (1) surrounded by the skull and the vertebral column
 - (2) includes the thoracic and abdominopelvic cavities
 - (3) contains the brain and spinal cord
 - (4) located more anteriorly
 - (5) contains the heart, lungs, and many digestive organs
8. Radiographs. List the following structures, from darkest (black) to lightest (white), as they would appear on an X-ray film. Number the darkest one 1, the next darkest 2, and so on.
- (a) soft tissue
 - (b) femur (bone of the thigh)
 - (c) air in lungs
 - (d) gold (metal) filling in a tooth
9. The ventral surface of the body is the same as its — surface.
(a) medial, (b) superior, (c) superficial, (d) anterior, (e) distal.

10. Match each serous membrane in column B with its description in column A.

Column A

- (1) covers the surface of the heart
- (2) forms the outer lining of the pericardium
- (3) lines the wall of the thoracic cavity
- (4) covers the outer surface of the small intestine

Column B

- (a) parietal pericardium
- (b) parietal pleura
- (c) visceral pericardium
- (d) visceral peritoneum

11. Which microscopic technique provides sharp pictures of three-dimensional structures at high magnification? (a) light microscopy, (b) X-ray microscopy, (c) scanning electron microscopy, (d) transmission electron microscopy.
12. Histology is the same as (a) pathological anatomy, (b) ultrastructure, (c) functional morphology, (d) surface anatomy, (e) microscopic anatomy.

Short Answer Essay Questions

13. Describe the anatomical position, and then assume this position.
14. Identify the organ system that each group of organs listed here is part of:
- (a) thymus, thyroid, ovary, pancreas
 - (b) nasal cavity, larynx, bronchi, lungs
 - (c) kidney, ureter, urethra
15. (a) Define bilateral symmetry. (b) Although many body structures are bilaterally symmetrical, much of the *abdomen* is not. Find a picture that demonstrates this lack of symmetry, and name some abdominal organs that are not symmetrical.
16. The following advanced imaging techniques are discussed in the text: CT, angiography, PET, sonography, and MRI. (a) Which of these techniques uses X rays? (b) Which uses radio waves and magnetic fields? (c) Which uses radioactive isotopes? (d) Which displays body regions in sections? You may have more than one answer to each question.
17. Give the formal regional term for each of these body areas: (a) arm, (b) chest, (c) thigh, (d) navel, (e) limbs.
18. Look ahead in this book to Figure 4.3 (pp. 68–71). Do you think that the micrographs in the figure are viewed by light microscopy, transmission electron microscopy, or scanning electron microscopy? Please explain your answer as fully as possible.
19. Construct sentences that use the following directional terms: superior/inferior; dorsal/ventral; medial/lateral; and superficial/deep. Table 1.1 gives examples such as “The forehead is superior to the nose,” but please use different examples from those in the table. For ideas, look at whole-body diagrams that show many structures, such as Figures 1.3 and 1.8.
20. The main cavities of the body include the abdominal and pelvic cavities. List three organs in each of these cavities.
21. Where would you be injured if you pulled a muscle in your axillary region, cracked a bone in your occipital region, or received a cut on a digit?
22. (a) The human body is designed as a tube within a tube. List three organs that are part of the inner tube and three structures that are components of the outer tube. (b) Give an example of segmentation in the human body.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Dominic's doctors strongly suspect he has a tumor in his brain. Which of the following medical imaging techniques—conventional X-ray imaging, angiography, PET, sonography, or MRI—would probably be best for precisely locating the tumor?
2. The Nguyen family was traveling in their van and had a minor accident. The children in the back seat were wearing lap belts, but they still sustained bruises around the abdomen and had some internal injuries. Why is the abdominal area more vulnerable to damage than others?
3. A patient had a hernia in his inguinal region, pain from an infected kidney in his lumbar region, and hemorrhoids in his perineal region. Explain where each of these regions is located.
4. A woman fell off a motorcycle. She tore a nerve in her axillary region, and she broke bones in her coxal, sacral, acromial, and fibular regions. Explain where each of these regions is located.
5. New anatomy students often mix up the terms *spinal cord*, *spinal column*, and *spine*. Look up these words in the index of this book or in a medical dictionary, define each one, and explain whether they are the same or different.
6. Using the list of word roots located in the inside covers of the text: (1) Look up the meaning of each root listed below. (2) Identify one

anatomical term used in this chapter that is derived from each root. (3) Define the anatomical term from your knowledge of the meaning of the word root.

super- , contra- , para- , ante- , mamm- , epi- , peri- , -graph , trans-



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CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 5.

PAL = Practice Anatomy Lab™

1. The integumentary system consists of the skin and its appendages (hair, sebaceous glands, sweat glands, and nails). The hypodermis, although not part of the integumentary system, is also considered in this chapter.
2. Skin functions to protect our body from bumps and scrapes, chemicals, invading microorganisms, water loss, and ultraviolet (UV) radiation. It also functions in body temperature regulation, excretion, production of vitamin D, and sensory reception.

The Skin and the Hypodermis (pp. 102–110)

Epidermis (pp. 103–105)

3. The epidermis is a keratinized stratified squamous epithelium. Its main cell type is the keratinocyte. From deep to superficial, its strata are the basale, spinosum, granulosum, lucidum, and corneum. The stratum lucidum occurs only in thick skin found on palms and soles.
4. The dividing cells of the stratum basale are the source of new keratinocytes for the growth and renewal of the epidermis.
5. In the stratum spinosum, keratinocytes contain strong pre-keratin intermediate filaments. In the stratum granulosum, keratinocytes contain keratohyalin granules, which combine with the pre-keratin filaments to form tension-resisting keratin. Stratum granulosum cells also secrete an extracellular waterproofing glycolipid. Keratinized cells of the stratum corneum protect the skin and are shed as skin flakes and dandruff.
6. Scattered among the keratinocytes in the deepest layers of the epidermis are pigment-producing melanocytes, tactile epithelial cells, and the dendritic cells of the immune system.

Dermis (pp. 106–108)

7. The leathery dermis, composed of connective tissue proper, is well supplied with vessels and nerves. Also located in the dermis are skin glands and hair follicles.
8. The superficial papillary layer consists of areolar connective tissue, whereas the deep reticular layer is dense irregular connective tissue. The papillary layer abuts the undulating undersurface of the epidermis and is responsible for the epidermal friction ridges that produce fingerprints. In the reticular layer, less dense regions between the collagen bundles produce cleavage lines. Flexure lines occur over joints, where the dermis attaches tightly to underlying structures.

Hypodermis (p. 109)

9. The hypodermis underlies the skin. Composed primarily of adipose tissue, it stores fat, insulates the body against heat loss, and absorbs and deflects blows. During weight gain, this layer thickens most markedly in the thighs and breasts of women and in the anterior abdominal wall of men.

Skin Color (pp. 109–110)

10. Skin color reflects the amounts of pigments (melanin and/or carotene) in the skin and the oxygenation level of hemoglobin in the dermal blood vessels.
11. Melanin, made by melanocytes and transferred to keratinocytes, protects keratinocyte nuclei from the damaging effects of UV radiation.

The epidermis also produces vitamin D under the stimulus of UV radiation.

Appendages of the Skin (pp. 110–114)

12. Skin appendages, which develop from the epidermis but project into the dermis, include hairs and hair follicles, sebaceous glands, sweat glands, and nails.

Nails (p. 110)

13. A nail is a scalelike modification of the epidermis that covers the dorsal tip of a finger or toe. The actively growing region is the nail matrix.

Hair and Hair Follicles (pp. 110–113)

14. A hair is produced by a tube-shaped hair follicle and consists of heavily keratinized cells. Each hair has an outer cuticle, a cortex, and usually a central medulla. Hairs have roots and shafts. Hair color reflects the amount and variety of melanin present.
15. A hair follicle consists of an epithelial root sheath that includes the hair matrix and connective tissue root sheath derived from the dermis. Stem cells, which renew the hair matrix and give rise to new epidermal cells, are in the epithelial root sheath. A knot of capillaries in the hair papilla nourishes the hair, and a nerve knot surrounds the hair bulb. Arrector pili muscles pull the hairs erect and produce goose bumps in response to cold or fear.
16. Fine and coarse hairs are called vellus hairs and terminal hairs, respectively. At puberty, under the influence of androgens, terminal hairs appear in the axillae and pubic regions in both sexes.
17. Hairs grow in cycles that consist of growth and resting phases. Hair thinning results from factors that lengthen follicular resting phases, including natural age-related atrophy of hair follicles and expression of the male pattern baldness gene during adulthood.

Sebaceous Glands (pp. 113–114)

18. Sebaceous glands are simple alveolar glands that usually empty into hair follicles. Their oily holocrine secretion is called sebum.
19. Sebum lubricates the skin and hair, slows water loss across the skin, and acts as a bactericidal agent. Sebaceous glands secrete increased amounts of sebum at puberty under the influence of androgens. Blocked and infected sebaceous glands lead to pimples and acne.

Sweat Glands (p. 114)

20. Eccrine sweat glands are simple coiled tubular glands that secrete sweat, a modified filtrate of the blood. Evaporation of sweat cools the skin and the body.
21. Apocrine sweat glands, which produce pheromones, occur primarily in the axillary, anal, and genital regions. Their secretion contains proteins and fatty acids; bacterial action on this secretion causes body odor.

PAL Histology/Integumentary System

Disorders of the Integumentary System (pp. 114–116)

22. The most common skin disorders result from microbial infections.

Burns (pp. 115–116)

23. In severe burns, the initial threat is loss of body fluids leading to circulatory collapse. The secondary threat is overwhelming infection.

24. The extent of a burn may be estimated by using the rule of nines. The severity of burns is indicated by the terms *first-*, *second-*, and *third-degree*. Third-degree burns harm the full thickness of the skin and require grafting for successful recovery.

Skin Cancer (p. 116)

25. The major risk factor for skin cancer is exposure to UV sunlight.
26. Basal cell carcinoma and squamous cell carcinoma are the most common types of skin cancer and usually are curable if detected early. Melanoma, a cancer of melanocytes, is less common but dangerous. The ABCD or ABCD(E) rule can be used to examine a mole or spot for the possibility of melanoma.

The Skin Throughout Life (p. 117)

27. Epidermis develops from embryonic ectoderm; dermis and hypodermis develop from mesoderm; and melanocytes develop from neural crest cells.
28. At 5–6 months, a fetus has a downy lanugo coat. Fetal sebaceous glands produce vernix caseosa that protects the skin within the amniotic sac.
29. In old age, the skin thins and loses elasticity. Damage from sunlight leads to wrinkles, age spots, and loose and leathery skin; this reflects a loss of collagen and accumulation of elastin-containing material in the dermis.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Which epidermal cell type functions in the immune system? (a) keratinocyte, (b) melanocyte, (c) dendritic cell, (d) tactile epithelial cell.
- Match each epidermal layer in column B to its description in column A.

Column A

- ____ (1) Desmosomes and shrinkage artifacts give its cells “prickly” projections.
- ____ (2) Its cells are flat, dead bags of keratin.
- ____ (3) Its cells divide, and it is also called the stratum germinativum.
- ____ (4) It contains keratohyalin and lamellated granules.
- ____ (5) It is present only in thick skin.

Column B

- (a) stratum basale
- (b) stratum corneum
- (c) stratum granulosum
- (d) stratum lucidum
- (e) stratum spinosum

- The ability of the epidermis to resist rubbing and abrasion is largely due to the presence of (a) melanin, (b) carotene, (c) collagen, (d) keratin.
- Skin color is determined by (a) melanin, (b) carotene, (c) oxygenation level of the blood, (d) all of these.
- What is the major factor accounting for the waterproof nature of the skin? (a) desmosomes in stratum corneum, (b) glycolipid between stratum corneum cells, (c) the thick insulating fat of the hypodermis, (d) the leathery nature of the dermis.
- Circle the false statement about vitamin D: (a) Dark-skinned people make no vitamin D. (b) If the production of vitamin D is inadequate, one may develop weak bones. (c) If the skin is not exposed to sunlight, one may develop weak bones. (d) Vitamin D is needed for the uptake of calcium from food in the intestine.
- Use logic to deduce the answer to this question. Given what you know about skin color and skin cancer, the highest rate of skin cancer on earth occurs among (a) blacks in tropical Africa, (b) scientists in research stations in Antarctica, (c) whites in northern Australia, (d) Norwegians in the United States, (e) blacks in the United States.

- An arrector pili muscle (a) is associated with each sweat gland, (b) causes the hair to stand up straight, (c) enables each hair to be stretched when wet, (d) squeezes hair upward so it can grow out.
- Sebum (a) lubricates the skin and hair; (b) consists of dead cells and fatty substances; (c) collects dirt, so hair has to be washed; (d) all of these.
- An eccrine sweat gland is a ____ gland: (a) compound tubular, (b) compound tubuloacinar, (c) simple squamous, (d) simple tubular.
- Identify which embryonic layer listed in column B forms each of the skin structures in column A.

Column A

- ____ (1) hypodermis
- ____ (2) sebaceous gland
- ____ (3) epidermis
- ____ (4) dermis
- ____ (5) melanocytes

Column B

- (a) ectoderm
- (b) mesoderm
- (c) endoderm
- (d) neural crest

- The reticular layer of the dermis (a) provides strength and elasticity to the skin, (b) is composed of loose connective tissue, (c) insulates to prevent heat loss, (d) forms the dermal papilla.
- Match the skin structures in column B with their function listed in column A.

Column A

- ____ (1) protection from ultraviolet radiation
- ____ (2) insulation, energy storage
- ____ (3) waterproofing and prevention of water loss
- ____ (4) temperature regulation
- ____ (5) initiation of an immune response to invading bacteria
- ____ (6) excretion of water, urea, and salts
- ____ (7) help in bonding the epithelium to the dermis

Column B

- (a) dendritic cells
- (b) dermal vascular plexuses
- (c) papillary layer of the dermis
- (d) hypodermis
- (e) melanocytes
- (f) stratum corneum
- (g) eccrine sweat glands
- (h) reticular layer of the dermis

14. Thick skin differs from thin skin in (a) the thickness of the stratum spinosum, (b) the presence of an additional layer, the stratum granulosum, (c) thickness of the stratum corneum, (d) the distribution of sweat glands.
15. From the list of tissues in column B, identify the primary tissue that forms each of the structures in column A.

Column A

- (1) epidermis
- (2) reticular layer of the dermis
- (3) hypodermis
- (4) papillary layer of the dermis
- (5) apocrine sweat glands
- (6) hair follicle
- (7) nails

Column B

- (a) dense irregular connective tissue
- (b) dense regular connective tissue
- (c) areolar connective tissue
- (d) epithelial tissue
- (e) adipose tissue

Short Answer Essay Questions

16. Is a bald man really hairless? Explain.
17. Explain why thin skin is also called hairy skin, and why thick skin is also called hairless skin. (Note their locations.)
18. Distinguish first-, second-, and third-degree burns.
19. Why does skin that is exposed to sunlight age so much more than nonexposed skin?
20. Explain why no skin cancers originate from stratum corneum cells.
21. Explain each of these familiar phenomena in terms of what you learned in this chapter: (a) goose bumps, (b) dandruff, (c) stretch marks from gaining weight, (d) leaving fingerprints, (e) the almost hairless body of humans, (f) getting gray hairs.
22. Eric, an anatomy student, said it was so hot one day that he was “sweating like a pig.” His professor overheard him and remarked, “That is a stupid expression, Eric. No pig ever sweats nearly as much as a person does!” Explain her remark.
23. List three functions of the skin.
24. After studying the skin in anatomy class, Toby grabbed the large “love handles” around his own abdomen and said, “I have a thick hypodermis, but this layer performs some valuable functions!” What are the functions of the hypodermis?
25. What type of tissue(s) form each of the following structures? (a) dermis, (b) epidermis, (c) hypodermis. What embryonic germ layer is the source of each?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. What are the two most important clinical problems encountered by severely burned patients? Explain each in terms of the absence of skin.
2. Dean, a 40-year-old beach boy, tells you that his suntan made him popular when he was young. Now his face is wrinkled, and he has several moles that are growing rapidly and are as large as coins. When he shows you the moles, you immediately think “ABCD.” What do these letters mean, and what disease may Dean have?
3. Long-term patients confined to hospital beds are turned every 2 hours. Why? Why is this effective?
4. Carmen slipped on some ice and split her chin on the sidewalk. As the emergency room physician was giving her six stitches, he remarked that the split was right along a cleavage line. How cleanly is her wound likely to heal, and is major scarring likely to occur?
5. A man got his finger caught in a machine at the factory, and his entire nail was torn off his right index finger. The nail parts lost were the body, root, bed, matrix, and eponychium. Is this nail likely to grow back? Why or why not?
6. On a diagram of the human body, mark off various regions according to the rule of nines. What percent of the total body surface is affected if someone is burned (a) over the entire posterior trunk and buttocks? (b) over an entire lower limb? (c) on the entire front of the left upper limb?
7. Why are melanomas the most common type of skin cancer to metastasize? (Recall that melanocytes are formed from neural crest tissue, an embryonic tissue that wanders extensively during early development.)
8. What are the harmful effects of UV radiation, and how is UV radiation beneficial to our well-being?



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Bones and Skeletal Tissues

6

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The Skeleton Throughout Life 142



Osteons in human compact bone (color-enhanced image).

ossification timetable that the age of a fetus in the womb can be determined from X-ray images or sonograms of the fetal skeleton.

At birth, all bones are relatively smooth and featureless. However, as the child increasingly uses its muscles, the bones develop projections and other markings (see Table 6.1). Children's bones are not particularly weak, but the cartilage of their epiphyseal plates is not as strong as bone. Thus, childhood injuries often split the epiphyses off from the diaphysis. To treat such injuries, the bone parts are manipulated back into place, then stabilized with metal pins.

As mentioned earlier, the skeleton keeps growing until the age of 18 to 21 years. In children and adolescents, the rate of bone formation exceeds the rate of bone resorption. In young adults, these two processes are in balance. In old age, resorption predominates. Beginning at about age 40, the mass of both compact and spongy bone declines. Among

young adults, skeletal mass is generally greater in men than in women. Age-related bone loss is greater in women than in men.

As bone mass declines with age, other changes occur. An increasing number of osteons remain incompletely formed, and mineralization is less complete. The amount of nonliving compact bone increases, reflecting a diminished blood supply to the bones in old age.

check your understanding

22. At what age do bones begin to ossify? At what age does bone mass begin to decline?
23. Why is age-related bone loss greater in women than in men?

For answers, see Appendix B.

RELATED CLINICAL TERMS

BONE GRAFT Transplantation of a piece of bone from one part of a person's skeleton to another part where bone has been damaged or lost. The graft, often taken from the crest of the iliac bone of the hip, encourages regrowth of lost bone.

BONY SPUR An abnormal projection on a bone due to bone overgrowth; is common in aging bones.

OSTEALGIA (os"te-al'je-ah) (*algia* = pain) Pain in a bone.

OSTEOMYELITIS (os"te-o-mi-ě-li'tis; "bone and marrow inflammation"). Bacterial infection of the bone and bone marrow. The pathogen enters bones either from infections in surrounding tissues or through the bloodstream, or follows a compound bone fracture.

PATHOLOGIC FRACTURE Fracture occurring in a diseased bone and involving slight or no physical trauma. An example is a broken hip caused by osteoporosis: The hip breaks first, causing the person to fall.

TRACTION ("pulling") Placing a sustained tension on a region of the body to keep the parts of a fractured bone in the proper alignment. Traction also keeps the bone immobilized as it heals. Without traction of the lower limb, for example, strong spasms of the large muscles of the thigh would separate the fracture in a broken femur. Traction is also used to immobilize fractures of the vertebral column, because any movement there could crush the spinal cord.

CHAPTER SUMMARY

Cartilages (pp. 123–125)

Location and Basic Structure (p. 123)

1. Important cartilages in the adult body are cartilage in the external ear and nose, articular cartilages, costal cartilages, the epiglottis, cartilages of the respiratory tubes, cartilage in intervertebral discs, and cartilage discs in certain movable joints. Cartilage makes up most of the embryonic skeleton.
2. Perichondrium is the girdle of dense connective tissue that surrounds a piece of cartilage.
3. Cartilage is resilient: Water squeezed out of its matrix by compression rushes back in as the compression eases, causing the cartilage to spring back.
4. Growing cartilage enlarges quickly because the small amount of matrix it manufactures attracts a large volume of water. Cartilage is avascular and is weak in resisting shearing stresses.

Types of Cartilage (pp. 123–125)

5. The locations of hyaline, elastic, and fibrocartilage are shown in Figure 6.1.
6. Hyaline cartilage is the most common type. Its matrix contains fine collagen fibrils. Elastic cartilage resembles hyaline cartilage, but its matrix also contains elastic fibers that make it pliable. Fibrocartilage contains thick collagen fibers and can resist both compression and extreme tension.

Growth of Cartilage (p. 125)

7. Cartilages grow from within (interstitial growth) and externally, as chondroblasts in the perichondrium add cartilage tissue at the periphery (appositional growth). In adults, damaged cartilage regenerates poorly. In the growing and aged skeleton, cartilage calcifies.

Bones (pp. 125–139)

8. Skeletal bones are considered organs because they contain different tissue types.

Functions of Bones (pp. 125–126)

9. Bones support body weight, act as levers for muscles to pull on, protect soft organs, store calcium, and contain bone marrow that makes blood cells. Bone cells also function in energy metabolism by influencing blood sugar regulation.

Bone Tissue (p. 126)

10. Bone consists of cells plus an extracellular matrix. The matrix contains organic substances secreted by osteoblasts, including collagen, which gives bone tensile strength. The organic part of bone matrix is called osteoid. Calcium phosphate salts (hydroxyapatites) crystallize in this matrix, making bone hard and able to resist compression.
11. The cells in bone tissue are osteogenic stem cells; osteoblasts, which secrete osteoid; osteocytes, which maintain the bone matrix; and osteoclasts, which destroy bone tissue.

Classification of Bones (pp. 126–127)

12. Bones are classified on the basis of their shape as long, short, flat, or irregular.

Gross Anatomy of Bones (pp. 128–131)

13. Bones have an external layer of compact bone and are filled internally with spongy bone, in which trabeculae are arranged in networks.
14. A long bone is composed of a diaphysis or shaft, and epiphyses or ends. Epiphyseal vessels serve each epiphysis, and nutrient vessels serve the diaphysis. Bone marrow occurs within the spongy bone and in a central medullary (marrow) cavity. A periosteum covers the outer surface of bones, and an endosteum covers the inner bone surfaces.
15. Flat bones consist of two plates of compact bone separated by a layer of spongy bone.
16. The density of bone material and the magnitude of bending stresses decline from the superficial to the deep regions of the bones. Thus, the strongest forces occur at the periphery, where they are resisted by the strong compact bone. The spaces within bones lighten the skeleton and contain bone marrow.
17. The trabeculae of spongy bone appear to be arranged along the dominant lines of stress experienced by the bone.
18. Bone markings are landmarks that represent sites of muscle attachment, articulation, and passage of blood vessels and nerves (see Table 6.1, p. 131).

Microscopic Structure of Bone (pp. 130–134)

19. An important structural unit in compact bone is the osteon, essentially a pillar consisting of a central canal surrounded by concentric lamellae. Osteocytes, embedded in lacunae, are connected to each other and to the central canal by canaliculi.
20. Bone lamellae are concentric tubes of bone matrix. The collagen fibers in adjacent lamellae run in roughly opposite directions. This arrangement gives bone tissue great strength in resisting torsion (twisting).
21. Spongy bone consists of trabeculae containing several layers of lamellae and osteocytes, but no osteons.

Bone Development and Growth (pp. 134–137)

22. Flat bones of the skull and the clavicle form by intramembranous ossification of embryonic mesenchyme. A network of bone tissue woven around capillaries appears first and is then remodeled into a flat bone.

23. Most bones develop by endochondral ossification of a hyaline cartilage model, starting in the late embryonic period (week 8). The stages of development of a long bone are (1) formation of a bone collar around the diaphysis; (2) calcification and cavitation in the center of the diaphysis; (3) growth of a periosteal bud into the center of the shaft, and formation of the first bone trabeculae; (4) appearance of the medullary cavity and continued rapid growth throughout the fetal period; near birth, secondary ossification centers occur in the epiphyses; (5) ossification of the epiphyses and continued growth in length at the epiphyseal plates through adolescence.
24. The growing cartilage of the fetal epiphyses and the postnatal epiphyseal plates is organized into several zones, which allow rapid growth. These zones are explained in Figure 6.12.
25. Endochondral bones lengthen during youth through the growth of epiphyseal plate cartilages, which close in early adulthood.
26. Bones increase in width through appositional growth.

Bone Remodeling (pp. 137–138)

27. New bone tissue is continuously deposited and resorbed in response to hormonal and mechanical stimuli. Together, these processes are called bone remodeling. Bone remodeling in adults occurs in the endosteum.
28. Osteoclasts break down bone tissue by secreting digestive enzymes and acid onto bone surfaces. This process releases Ca^{2+} and PO_4^{3-} into the blood. Parathyroid hormone stimulates this resorption of bone.
29. Osteoid is secreted by osteoblasts at areas of bone deposit. Calcium salt is then deposited in the osteoid.
30. Compressive forces and gravity acting on the skeleton help maintain bone strength, because bones thicken at sites of stress.

Repair of Bone Fractures (pp. 139, 140)

31. Fractures are treated by open or closed reduction. Healing involves the formation of a hematoma, a fibrocartilaginous callus, and a bony callus, and then a remodeling of the callus into the original bone pattern.

Disorders of Bones (pp. 139–142)

32. Osteoporosis is a condition in which bone breakdown outpaces bone formation, causing bones to weaken. Postmenopausal women are most susceptible.
33. Osteomalacia and rickets occur when bones are inadequately mineralized, making them soft and deformed. The most common cause is inadequate intake or production of vitamin D.
34. Paget's disease is characterized by excessive and abnormal remodeling of bone.
35. Osteosarcoma is the most common form of bone cancer.

The Skeleton Throughout Life (pp. 142–143)

36. Bone formation in the fetus occurs in a predictable and precisely timed manner.
37. The mass of the skeleton increases dramatically during puberty and adolescence, when bone formation exceeds resorption.
38. Bone mass is constant in young adulthood, but beginning at about age 40, bone resorption exceeds formation.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Which is a function of the skeletal system? (a) support, (b) blood cell formation, (c) mineral storage, (d) providing levers for muscle activity, (e) all of these.
- Articular cartilages are located (a) at the ends of bones, (b) between the ribs and the sternum (breastbone), (c) between the epiphysis and diaphysis, (d) in the nose.
- The perichondrium of cartilage is similar to the ____ of bone. (a) articular cartilages, (b) spongy bone layer, (c) osteons, (d) marrow, (e) periosteum.

- Use the key to indicate the type of cartilage that forms each of the structures below.

Key: (a) hyaline cartilage (b) elastic cartilage (c) fibrocartilage

____ (1) articular cartilage covering the surfaces of movable joints

____ (2) the epiglottis

____ (3) the thyroid cartilage

____ (4) the menisci in the knee

____ (5) the embryonic skeleton

- Indicate whether each of the following statements is true (T) or false (F).

____ (1) Cartilage is more resilient than bone.

____ (2) Cartilage is especially strong in resisting shear (bending and twisting) forces.

____ (3) Cartilage can grow faster than bone in the growing skeleton.

____ (4) In the adult skeleton, cartilage heals and regenerates faster than bone when damaged.

____ (5) Neither bone nor cartilage contains capillaries.

____ (6) Bone tissue contains very little water compared to other connective tissues, while cartilage tissue contains a large amount of water.

____ (7) Nutrients diffuse quickly through cartilage matrix but very poorly through the solid bone matrix.

- A bone that has essentially the same width, length, and height is most likely (a) a long bone, (b) a short bone, (c) a flat bone, (d) an irregular bone.

- The shaft of a long bone is properly called the (a) epiphysis, (b) periosteum, (c) diaphysis, (d) compact bone.

- Match the function of bone markings described in column B with the bone markings listed in column A.

Column A

____ (1) trochanter

____ (2) condyle

____ (3) foramen

____ (4) process

____ (5) facet

____ (6) tuberosity

Column B

(a) attachment site for muscle or ligament

(b) forms a joint surface

(c) passageway for vessels or nerves

- The osteon exhibits (a) a central canal containing blood vessels, (b) concentric lamellae of matrix, (c) osteocytes in lacunae, (d) all of these.

- The flat bones of the skull develop from (a) areolar tissue, (b) hyaline cartilage, (c) mesenchyme membranes, (d) compact bone.

- The following events apply to the endochondral ossification process as it occurs in the primary ossification center. Put these events in their proper order by assigning each a number (1–6).

____ (a) Cartilage in the diaphysis calcifies, and chondrocytes die and disintegrate, leaving cavities.

____ (b) A collar of bone is laid down around the hyaline cartilage model just deep to the periosteum.

____ (c) The periosteal bud invades the center of the diaphysis.

____ (d) The perichondrium of shaft becomes more vascularized and becomes a periosteum.

____ (e) Osteoblasts first deposit bone tissue around the cartilage spicules within the diaphysis.

____ (f) Osteoclasts remove the bone from the center of the diaphysis, leaving a medullary cavity that then houses marrow.

- The remodeling of bone tissue is a function of which cells? (a) chondrocytes and osteocytes, (b) osteoblasts and osteoclasts, (c) chondroblasts and osteoclasts, (d) osteoblasts and osteocytes.

- Osteogenic cells are located in (a) the lacunae, (b) the fibrous layer of the periosteum, (c) the endosteum, (d) the perichondrium, (e) the growth zone of the epiphysis.

- A fracture in which the bone penetrates soft tissue and skin is (a) greenstick, (b) compound, (c) simple, (d) comminuted, (e) compression.

- The disorder in which bones are porous and thin but the chemistry of the bone matrix remains normal is (a) osteomalacia, (b) osteoporosis, (c) osteomyelitis, (d) Paget's disease.

- Where within an epiphyseal plate is the calcified cartilage located? (a) nearest the diaphysis, (b) in the medullary cavity, (c) farthest from the diaphysis, (d) in the primary ossification center, (e) all of these.

- Endosteum is in all these places, except: (a) around the exterior of the femur, (b) on the trabeculae of spongy bone, (c) on the lining of the central canal of an osteon, (d) often in direct contact with bone marrow.

- Match the cells listed in column B with the descriptions in column A. More than one answer may be correct.

Column A

____ (1) located within lacunae

____ (2) secrete matrix

____ (3) maintain bone matrix

____ (4) destroy bone tissue

____ (5) located in the endosteum

Column B

(a) osteoblasts

(b) osteocytes

(c) osteoclasts

(d) chondrocytes

Short Answer Essay Questions

19. Explain (a) why cartilages are resilient and (b) why cartilage can grow so quickly in the developing skeleton.
20. Some anatomy students are joking between classes, imagining what a bone would look like if it had spongy bone on the outside and compact bone on the inside, instead of the other way around. You tell the students that such an imaginary bone would be of poor mechanical design and would break very easily when bent. Explain why this is so.
21. When and why do the epiphyseal plates close?
22. During what period of life does skeletal mass increase dramatically? Begin to decline? Why are fractures most common in older adults?
23. In a piece of cartilage in the young skeleton, interstitial and appositional growth occur together. Compare and contrast interstitial and appositional growth.
24. Photocopy a picture of a skeleton, and then use a red pencil to color its membrane bones and a blue pencil to color its endochondral bones.
25. Differentiate the following: osteoclast, osteocyte, osteoblast, osteon.
26. List three structural features of cartilage and bone tissue that are similar. List three structural features that are different.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Explain why people confined to wheelchairs because of paralyzed lower limbs have thin, weak bones in their thighs and legs.
2. While walking home from class, 52-year-old Ike fell. He broke a bone and damaged cartilage in his knee. Assuming no special tissue grafts are made, which will probably heal faster, the bone or the cartilage? Why?
3. Carlos went to weight-lifting camp in the summer between seventh and eighth grade. He noticed that the trainer put tremendous pressure on participants to improve their strength. After an especially vigorous workout, Carlos's arm felt extremely sore and weak around the elbow. He went to the camp doctor, who took X-ray photos and then told him that the injury was serious because the "end, or epiphysis, of his upper arm bone was starting to twist off." What had happened? Could the same thing happen to Carlos's 23-year-old sister, Selena, who was also starting a weight-lifting program? Why or why not?
4. Ming posed the following question: "If the epiphyseal growth plates are growing so fast, why do they stay thin? Growing things are supposed to get larger or thicker, but these plates remain the same thickness." How would you answer her?
5. Old Norse stories tell of a famous Viking named Egil, an actual person who lived around A.D. 900. His skull was greatly enlarged and misshapen, and the cranial bones were hardened and thickened (6 cm, or several inches, thick). After he died, his skull was dug up, and it withstood the blow of an ax without damage. In life, he had headaches from the pressure exerted by enlarged vertebrae on his spinal cord. So much blood was diverted to his bones to support their extensive remodeling that his fingers and toes always felt cold, and his heart was damaged through overexertion. What bone disorder did Egil probably have?
6. Bernice, a 75-year-old woman, stumbled slightly while walking, then felt a terrible pain in her left hip. At the hospital, X-ray pictures revealed that the hip was broken. Furthermore, the spongy bone throughout her spine was very thin. What condition does Bernice probably have?
7. Why might repeated pregnancies cause a woman to develop osteomalacia?
8. Traditional treatments for osteoporosis address calcium deficiencies in the diet and the importance of weight-bearing exercise. Describe how weight-bearing exercise improves bone mass.



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Bones, Part 1: The Axial Skeleton

7

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The Axial Skeleton Throughout Life 177



A healthy lumbar spine, sagittal view (colored X ray).

RELATED CLINICAL TERMS

CRANIOTOMY (“cutting the skull”) Surgery to remove part of the cranium, usually done to gain access to the brain—for example, to remove a brain tumor, a blood clot, or a sample of brain tissue for a biopsy. The piece of skull is removed by drilling a series of round holes through the bone at regular intervals to outline a square and then cutting between these holes with a stringlike saw. At the end of the operation, the square piece of bone is replaced, and it heals normally.

LAMINECTOMY (lam’i-nek’to-me; “lamina-cutting”) Surgical removal of a vertebral lamina. Laminectomies are usually done to reach and relieve a herniated disc.

ORTHOPEDIST (or’tho-pe’dist) or **ORTHOPEDIC SURGEON** A physician who specializes in restoring lost function or repairing damage to bones and joints.

SPINAL FUSION Surgical procedure involving insertion of bone chips as a tissue graft to stabilize a portion of the vertebral column, particularly after the fracture of a vertebra or the prolapse of a disc.

WHIPLASH An injury to the neck region caused by a rapid sequence of hyperextension followed by hyperflexion of the neck. Often results when a car is hit from the rear. Damage and pain usually result from stretching of the ligaments and joints between the neck vertebrae, and torn neck muscles. Treatment typically involves use of a neck brace, painkillers, muscle-relaxing drugs, and physical therapy.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 7.

PAL = Practice Anatomy Lab™

1. The axial skeleton forms the long axis of the body. Its parts are the skull, vertebral column, and thoracic cage. The appendicular skeleton, by contrast, consists of the pectoral (shoulder) and pelvic girdles and the long bones of the limbs.

The Skull (pp. 149–167)

2. The cranium forms the vault and base of the skull and protects the brain. The facial skeleton provides openings for the eyes, openings for respiratory and digestive passages, and areas of attachment for facial muscles.
3. Almost all bones of the skull are joined by immobile sutures.
4. The eight bones of the cranium are the paired parietal and temporal bones and the unpaired frontal, occipital, sphenoid, and ethmoid bones (see Table 7.1, pp. 162–163).
5. The 14 facial bones are the paired maxillae, zygomatics, nasals, lacrimals, palatines, and inferior nasal conchae, plus the unpaired mandible and vomer (see Table 7.1).
6. The nasal cavity and orbits are complicated regions of the skull, each formed by many bones (see Figures 7.14 and 7.16).
7. The air-filled paranasal sinuses occur in the frontal, ethmoid, sphenoid, and maxillary bones. They are extensions of the nasal cavity, to which they are connected.
8. The bowed hyoid bone in the anterior neck serves as a movable base for the tongue, among other functions.

The Vertebral Column (pp. 167–174)

9. The vertebral column includes 26 irregular bones: 24 vertebrae plus the sacrum and coccyx.
10. The vertebral column has five major regions: the cervical vertebrae (7), the thoracic vertebrae (12), the lumbar vertebrae (5), the sacrum, and the coccyx. The cervical and lumbar curvatures are concave posteriorly, and the thoracic and sacral curvatures are convex posteriorly.

11. The thoracic and sacral curvatures are primary curvatures, present at birth. The cervical curvature becomes pronounced when a baby starts to lift its head, and the lumbar curvature develops when a toddler starts to walk. These are secondary curvatures.
12. The spinal column is supported by a number of ligaments, including the anterior and posterior longitudinal ligaments, which run along the bodies of the vertebrae from the neck to the sacrum; and the ligamentum flavum, an especially strong elastic ligament running between the lamina of adjacent vertebrae.
13. Intervertebral discs, with their nucleus pulposus cores and anulus fibrosus rings, act as shock absorbers and give flexibility to the spine. Herniated discs usually involve rupture of the anulus followed by protrusion of the nucleus.
14. With the exception of C₁, all cervical, thoracic, and lumbar vertebrae have a body, two transverse processes, two superior and two inferior articular processes, a spinous process, and a vertebral arch.
15. The atlas and axis (C₁ and C₂) are atypical vertebrae. The ringlike atlas supports the skull and helps make nodding movements possible. The axis has a dens that helps the head to rotate.
16. Special characteristics distinguish the cervical, thoracic, and lumbar vertebrae from one another (see Table 7.2, p. 172). The orientation of the articular facets determines the movements possible in the different regions of the spinal column. The sacrum and coccyx, groups of fused vertebrae, contribute to the bony pelvis.

The Thoracic Cage (pp. 174–176)

17. The thoracic cage includes the 12 pairs of ribs, the sternum, and the thoracic vertebrae.
18. The sternum consists of the manubrium, body, and xiphoid process. The sternal angle marks the joint between the manubrium and body, where the second ribs attach.
19. The first seven pairs of ribs are called true ribs; the rest are false ribs. The eleventh and twelfth are called floating ribs. A typical rib consists of a head with facets, a neck, a tubercle, and a shaft. A costal cartilage occurs on the ventral end of each rib.

PAL Human Cadaver/Axial Skeleton**Disorders of the Axial Skeleton (pp. 176–177)**

20. Cleft palate, a congenital malformation, results when the bones of the hard palate do not fuse medially. Stenosis of the lumbar spine is a pathological narrowing of the vertebral canal in the lumbar region. Scoliosis, kyphosis, and lordosis are three types of abnormal spinal curvature.

The Axial Skeleton Throughout Life (pp. 177–178)

21. Fontanelles are membrane-covered regions between the cranial bones in the infant skull. They allow growth of the brain and ease birth passage.

22. Most skull bones are membrane bones. The skull's only endochondral bones are most of the occipital and sphenoid, the petrous and mastoid parts of the temporal, and the ethmoid.
23. Growth of the cranium early in life is closely related to the rapid growth of the brain. Enlargement of the face in late childhood follows tooth development and expansion of the nose, paranasal sinuses, and chewing muscles.
24. In old age, the intervertebral discs thin. This, along with osteoporosis, leads to a gradual decrease in height.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, See Appendix B.

1. Match the bones in column B to their descriptions in column A. (Some entries in column A will require more than one answer from column B.)

Column A

- (1) bones connected by the coronal suture
- (2) keystone bone of the cranium
- (3) keystone bone of the face
- (4) bones that form the hard palate
- (5) bone that contains the foramen magnum
- (6) forms the chin
- (7) contain paranasal sinuses
- (8) contains mastoid air cells

Column B

- (a) ethmoid
- (b) frontal
- (c) mandible
- (d) maxillary
- (e) occipital
- (f) palatine
- (g) parietal
- (h) sphenoid
- (i) temporal

2. Herniated intervertebral discs tend to herniate (a) superiorly, (b) anterolaterally, (c) posterolaterally, (d) laterally.
3. The parts of the sternum that articulate at the sternal angle are (a) xiphoid and body, (b) xiphoid and manubrium, (c) manubrium and body, (d) second ribs.
4. The only rib whose shaft is flattened in the horizontal plane, instead of vertically, is the (a) first rib, (b) seventh rib, (c) eleventh rib, (d) twelfth rib.
5. The name of the first cervical vertebra is (a) atlas, (b) axis, (c) occiput, (d) vertebra prominens.
6. Match the vertebrae listed in column B with the features in column A.

Column A

- (1) no spinous process
- (2) transverse foramen
- (3) superior articular facets
- (4) dens process
- (5) transverse costal facets
- (6) kidney-shaped body
- (7) forked spinous process

Column B

- (a) atlas only
- (b) axis only
- (c) cervical vertebrae
- (d) thoracic vertebrae
- (e) lumbar vertebrae
- (f) all vertebrae

— (8) circular vertebral foramen

— (9) transverse process

— (10) articular facets directed medially/laterally

7. Match the foramen in column B with the bone in column A in which it is located.

Column A

- (1) ethmoid bone
- (2) maxillary bone
- (3) sphenoid bone
- (4) occipital bone
- (5) temporal bone

Column B

- (a) hypoglossal canal
- (b) foramen ovale
- (c) external acoustic meatus
- (d) infraorbital foramen
- (e) olfactory foramina

Short Answer Essay Questions

8. In the fetus, how do the relative proportions of the cranium and face compare with those in the skull of a young adult?
9. Name and diagram the four normal vertebral curvatures. Which are primary and which are secondary?
10. List two specific structural characteristics each for cervical, thoracic, and lumbar vertebrae that would enable anyone to identify each type correctly.
11. (a) What is the function of intervertebral discs? (b) Distinguish the annulus fibrosus from the nucleus pulposus of a disc. (c) Which part herniates in the condition called prolapsed disc?
12. Is a floating rib a true rib or a false rib? Explain.
13. Briefly describe the anatomical characteristics and impairment of function seen in cleft palate.
14. Compare the skeleton of a young adult to that of an 85-year-old person, with respect to bone mass in general and the basic bony structure of the skull, thorax, and vertebral column.
15. Identify what types of movement are allowed by the lumbar region of the vertebral column, and compare these with the movements allowed by the thoracic region.
16. List the bones in each of the three cranial fossae.
17. Describe the important features of the sternum.
18. Define these structures in a way that shows you can tell them apart: vertebral arch, vertebral canal, vertebral foramen, and intervertebral foramen.

19. Describe where the four major fontanelles are located in relation to the major sutures of the skull.
20. Professor Ron Singer pointed to the foramen magnum of the skull and said, “That is where the food goes. The food passes down through this hole when you swallow.” Some of the students believed him, but others said this was a big mistake. Can you correct his statement?
21. In your anatomy course, you may be handed an isolated vertebra and asked to determine whether it is cervical, thoracic, or lumbar. Devise a reliable scheme for distinguishing these three types of vertebrae.
22. Describe how a typical true rib (for instance, the fifth rib) articulates with both the vertebral column and the sternum.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Antonio was hit in the face with a bad-hop grounder during baseball practice. An X-ray film revealed multiple fractures of the bones around an orbit. Name the bones that form the margins of an orbit.
2. Lindsey had polio as a child and was partially paralyzed in one lower limb for over a year. Although she is no longer paralyzed, she now has a severe lateral curvature of the lumbar spine. Explain what has happened, and name her condition.
3. Mr. Chester, a heavy beer drinker with a large potbelly, complained of severe lower back pains. After X-ray films were taken, he was found to have displacement of his lumbar vertebrae. What would this condition be called, and what would cause it?
4. Which region of the vertebral column (cervical, thoracic, or lumbar) is most likely to experience a herniated disc?
5. After falling off a horse, Mary complained of pain on the right side of her thorax that intensified when she took a deep breath or coughed. The emergency medical technician suspected a broken rib. Using palpation, how could the EMT identify the precise location of the injury?



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8

Bones, Part 2: The Appendicular Skeleton

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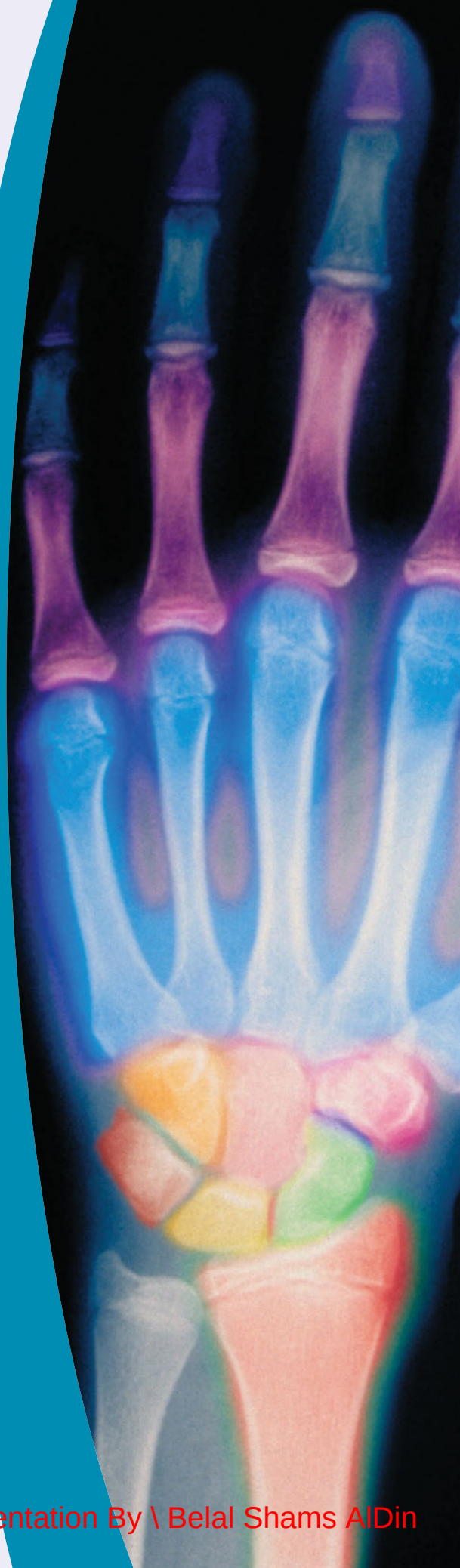
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Hand of a 12 year old (colored X ray).



RELATED CLINICAL TERMS

BUNION A deformity of the great toe involving lateral displacement of this digit and medial displacement of metatarsal 1. Also includes a bony swelling and a bursitis (p. 234) on the medial side of the head of the first metatarsal. Caused by tight or ill-fitting shoes (or, more rarely, by arthritis or genetic factors).

KNOCK-KNEE A deformity in which the two knees rub or knock together during walking. Knock-knee usually occurs in children because of irregular growth of the bones of the lower limb, injury to the ligaments, or injury to the bone ends at the knee.

LISFRANC INJURY Damage to the joints between the tarsal and metatarsal bones of the foot that results from violently twisting or

bending the anterior part of the foot on the posterior part, as can occur in a fall. Generally involves the cuneiforms and the first three metatarsals. The metatarsal bases may be dislocated and the intercuneiform joints damaged, often with fractures of these bones.

PELVIMETRY Measurement of the dimensions of the inlet and outlet of the pelvis, usually to determine whether it is of adequate size to allow normal delivery of a baby.

PODIATRY The specialized field dealing with the study and care of the foot, including its anatomy, disorders, and medical and surgical treatment.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 8.

PAL = Practice Anatomy Lab™

1. The appendicular skeleton consists of the pectoral and pelvic girdles and the bones of the upper and lower limbs.

The Pectoral Girdle (pp. 183–185)

2. The pectoral girdles are specialized for mobility. Each consists of a clavicle and a scapula and attaches an upper limb to the bony thorax.
3. The clavicles hold the arms laterally away from the thorax and transmit pushing forces from the upper limbs to the thorax.
4. Each triangular scapula articulates with a clavicle and a humerus. The borders, angles, and features of the scapula are summarized in Table 8.1 on p. 186.

The Upper Limb (pp. 184–191)

5. Each upper limb consists of 30 bones and is specialized for mobility. See Table 8.1, p. 186, for summary.
6. The skeleton of the arm consists solely of the humerus. The head of the humerus articulates with the glenoid cavity of the scapula, forming the shoulder joint.
7. The bones of the forearm are the radius and ulna. The radius is lateral and the ulna medial. Articulations between these bones are highly mobile, allowing the radius to rotate around the ulna. Proximally, the ulna contributes heavily to the elbow joint. Distally, the radius contributes to the wrist joint.
8. The bones of the hand are the carpals, metacarpals, and phalanges.

The Pelvic Girdle (pp. 191–194, 195)

9. The pelvic girdle, specialized for bearing weight, is composed of two hip bones that connect the lower limbs to the vertebral column. Together with the sacrum, the hip bones form the basinlike bony pelvis.
10. Each hip bone (coxal bone) consists of an ilium, ischium, and a pubis fused together. The cuplike acetabulum is at the Y-shaped region of fusion of these three bones.

11. The ilium is the superior flaring part of the hip bone. Each ilium forms a secure joint with the sacrum. The ischium is a curved bar of bone; when a person sits, the weight is borne by the ischial tuberosities. The V-shaped pubic bones join anteriorly at the pubic symphysis.

12. The pelvic inlet or pelvic brim, an oval ridge that includes the pubic crest, arcuate line of the ilium, and sacral promontory, separates the superior false pelvis from the inferior true pelvis.

13. The male pelvis is relatively deep and narrow, with larger, heavier bones; the female pelvis, which forms the birth canal, is comparatively shallower and wider (see Table 8.2, p. 195).

The Lower Limb (pp. 194–201)

14. The lower limb consists of the thigh, leg, and foot, and is specialized for weight bearing and locomotion. See Table 8.3, p. 196, for a summary.
15. The long, thick femur is the only bone of the thigh. Its ball-shaped head articulates with the acetabulum.
16. The bones of the leg are the tibia (which participates in both the knee and ankle joints), located medially, and the slender fibula laterally.
17. The bones of the foot are the tarsals, metatarsals, and phalanges. The most important tarsals are the calcaneus (heel bone) and the talus. The talus articulates with the leg bones at the ankle joint.
18. The foot is supported by three arches that distribute the weight of the body to the heel and ball of the foot.

PAL Human Cadaver/Appendicular Skeleton

Disorders of the Appendicular Skeleton (pp. 201–202)

19. Hip dysplasia (congenital dislocation of the hip) and clubfoot are common birth defects.

The Appendicular Skeleton Throughout Life (p. 202)

20. Fast growth of the lower limbs causes the upper-lower (UL) body ratio to change from 1.7:1 at birth to 1:1 at 10 years and beyond.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Match the bones listed in column B to their descriptions in column A. Answers in column B may be used more than once.

Column A	Column B
____ (1) bone of the axial skeleton to which the pectoral girdle attaches	(a) clavicle
____ (2) its features include the glenoid cavity and acromion process	(b) ilium
____ (3) its features include the ala, crest, and greater sciatic notch	(c) ischium
____ (4) membrane bone that transmits forces from upper limb to bony thorax	(d) pubis
____ (5) bone of pelvic girdle that articulates with the axial skeleton	(e) sacrum
____ (6) bone that bears weight during sitting	(f) scapula
____ (7) most anteroinferior bone of the pelvic girdle	(g) sternum
____ (8) bone of the axial skeleton to which the pelvic girdle attaches	

2. Match the bones in column B to their descriptions in column A. Answers in column B may be used more than once.

Column A	Column B
____ (1) articulates with the acetabulum and the tibia	(a) carpals
____ (2) its malleolus forms the lateral aspect of the ankle	(b) femur
____ (3) bone that articulates with the hand and wrist	(c) fibula
____ (4) the wrist bones	(d) humerus
____ (5) bone shaped much like a monkey wrench	(e) radius
____ (6) articulates with the capitulum of the humerus	(f) tarsals
____ (7) largest bone is the calcaneus	(g) tibia
	(h) ulna

3. Which of the following bony features is *not* near or in the shoulder joint? (a) acromion, (b) greater tubercle, (c) glenoid cavity, (d) anatomical neck of humerus, (e) deltoid tuberosity.
4. Which of the following bony features is not in or near the hip joint? (a) acetabulum, (b) sacral promontory, (c) greater trochanter, (d) neck of femur.

5. Which of the bones listed does *not* have a head? (a) radius, (b) femur, (c) ulna, (d) tibia, (e) fibula.
6. The greater and lesser tubercles are located on the (a) humerus, (b) coxal bone, (c) femur, (d) ankle, (e) tibia.
7. From the list of bones given, indicate all those that have a styloid process. (a) clavicle, (b) scapula, (c) radius, (d) ulna, (e) tibia, (f) fibula.
8. The lateral malleolus is the (a) proximal portion of the fibula, (b) distal portion of the tibia, (c) distal portion of the fibula, (d) proximal portion of the ulna, (e) bone in the middle ear cavity.
9. In the forearm, the radius is the ____ bone; therefore, the radial notch of the ulna points _____. (a) lateral/medially, (b) lateral/laterally, (c) medial/medially, (d) medial/laterally.
10. The scaphoid and lunate articulate with the (a) metacarpals, (b) radius and ulna, (c) radius, (d) tibia, (e) trapezium.

Short Answer Essay Questions

11. The major function of the pectoral girdle is mobility. (a) What is the major function of the pelvic girdle? (b) Relate these functional differences to the anatomical differences between the girdles.
12. List three differences between the male and female pelves.
13. Describe the function of the arches of the foot.
14. Briefly describe the anatomical characteristics and impairment of function seen in hip dysplasia.
15. Define and distinguish the true pelvis from the false pelvis.
16. Lance was a bright anatomy student, but he sometimes called the leg bones “fibia” and “tibula.” Correct this common mistake.
17. Draw the scapula in posterior view, and label all the borders, angles, fossae, and important features visible in this view.
18. Identify the associated bone and the location of each of the following bone features: (a) greater trochanter, (b) linea aspera, (c) trochlea, (d) coronoid process, (e) deltoid tuberosity, (f) greater tubercle, (g) greater sciatic notch.
19. (a) Which body regions do anatomists call the arm and the leg? (b) What is the *medial* side of the hand?
20. Tom Williams, a teaching assistant in anatomy class, picked up a bone and pretended it was a telephone. He put the big hole in this bone up to his ear and said, “Hello, obturator, obturator (operator, operator).” Name the bone and the structure he was helping the students to learn.
21. Name all the bones of the appendicular skeleton that have a tuberosity.
22. The hand and foot are structurally similar in many ways; they also show clear differences in structure related to their different functions. Describe the structural features of the foot that are clearly related to its weight-bearing and locomotory functions.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Malcolm injured himself after trying to break his fall with outstretched arms. The emergency room physician took one look at his shoulder and saw that Malcolm had a broken clavicle (and no other injury). Describe the position of Malcolm's shoulder. What part of the clavicle was most likely broken? Malcolm was worried about injury to the main blood vessels to his arm (the subclavian vessels), but he was told such injury was unlikely. Why could the doctor predict this?
2. Racheal, a hairdresser, developed flat feet. Explain why.
3. Justiniano worked in a poultry-packing plant, where his job was cutting open chickens and stripping out their visceral organs. After work, he typed for long hours on his computer keyboard, because he was writing a novel based on his work in the plant. Soon, his wrist and hand began to hurt whenever he flexed them, and he began to awaken at night with pain and tingling on the thumb half of his hand. What condition did he probably have?
4. Compare the bones of the upper limb with the bones of the lower limb. How are they similar; how are they different? How do these differences relate to different functions of the upper versus the lower limb?
5. The most common bone fracture in people under 75 years old is a wrist fracture, either fracture of the scaphoid or fracture of the distal radius (Colles' fracture). This injury results from falling on an outstretched hand. Why is the radius injured in this type of fall and not the ulna?



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9 Joints

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The Joints Throughout Life 236

A healthy knee joint (colored X ray).



Segmentation By \ Belal Shams AlDin



CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 9.

PAL = Practice Anatomy Lab™

1. Joints (articulations) are sites where elements of the skeleton meet. They hold bones together and allow various degrees of movement.

Classification of Joints (p. 207)

2. Joints are classified functionally as synarthrotic (no movement), amphiarthrotic (slight movement), or diarthrotic (free movement). They are classified structurally as fibrous, cartilaginous, or synovial.

Fibrous Joints (pp. 207–208)

3. In fibrous joints, the bones are connected by fibrous connective tissue. No joint cavity is present. Nearly all fibrous joints are synarthrotic (immovable).
4. The types of fibrous joints are sutures (between skull bones), syndesmoses (“ligament joints”), and gomphoses (articulation of the teeth with their sockets).

Cartilaginous Joints (pp. 208–209)

5. In cartilaginous joints, the bones are united by cartilage. No joint cavity exists.
6. Synchondroses are immovable joints of hyaline cartilage, such as epiphyseal plates. Symphyses are amphiarthrotic (slightly movable) fibrocartilage joints, such as intervertebral discs and the pubic symphysis.

Synovial Joints (pp. 209–221)

7. Most joints in the body are synovial. Synovial joints are diarthrotic (freely movable).

General Structure of Synovial Joints (pp. 209–221)

8. Synovial joints have a fluid-containing cavity and are covered by an articular capsule. The capsule has an outer fibrous region, often reinforced by ligaments, and an inner synovial membrane that produces synovial fluid. The articulating ends of bone are covered with impact-absorbing articular cartilages. Nerves in the capsule provide a sense of “joint stretch.” Some joints contain fibrocartilage discs (menisci), which distribute loads evenly and may allow two movements at one joint.
9. Synovial fluid is mainly a filtrate of the blood, but it also contains molecules that make it a friction-reducing lubricant.
10. Bursae and tendon sheaths are often associated with synovial joints. A bursa is a fibrous sac lined by a synovial membrane and containing synovial fluid. Tendon sheaths, which are similar to bursae, wrap around certain tendons. They act as lubricating devices that allow adjacent structures to move smoothly over one another.

General Function of Synovial Joints (pp. 211–212)

11. Synovial joints reduce friction. The cartilage-covered bone ends glide on a slippery film of synovial fluid squeezed out of the articular cartilages. This mechanism is called weeping lubrication.

Movements Allowed by Synovial Joints (pp. 212–214, 215)

12. Contracting muscles produce three common kinds of bone movements at synovial joints: gliding, angular movements (flexion, extension, abduction, adduction, and circumduction), and rotation.

13. Special movements include elevation and depression, protraction and retraction, supination and pronation of the forearm, opposition of the thumb, inversion and eversion of the foot, and dorsiflexion and plantar flexion of the foot.

Synovial Joints Classified by Shape (pp. 214, 216–219)

14. The shapes of the articular surfaces reflect the kinds of movements allowed at a joint. Joints are classified by shape as plane (nonaxial), hinge or pivot (uniaxial), condyloid or saddle (biaxial), or ball-and-socket (multiaxial) joints.

Factors Influencing the Stability of Synovial Joints (pp. 219–221)

15. Joints are the weakest part of the skeleton. Factors that stabilize joints are the shapes of the articulating surfaces, ligaments, and the tone of muscles whose tendons cross the joint.

Selected Synovial Joints (pp. 221–232)

16. The sternoclavicular joint is a saddle joint between the medial end of the clavicle and the manubrium of the sternum. This joint allows for elevation, depression, protraction, retraction, and slight rotation. It is an extremely stable joint.
17. The temporomandibular joint is a modified hinge joint formed by (1) the head of the mandible and (2) the mandibular fossa and articular tubercle of the temporal bone. This joint allows both a hingelike opening of the mouth and an anterior gliding of the mandible. It often dislocates anteriorly and is frequently the site of stress-induced temporomandibular disorders.
18. The shoulder (glenohumeral) joint is a ball-and-socket joint between the glenoid cavity and the head of the humerus. It is the body’s most freely movable joint. Its socket is shallow, and its capsule is lax and reinforced by ligaments superiorly and anteriorly. The tendons of the biceps brachii and the rotator cuff help stabilize the joint. The humerus often dislocates anteriorly, then inferiorly, at the shoulder joint.
19. The elbow is a hinge joint in which the ulna and radius articulate with the humerus. It allows flexion and extension. Its articular surfaces are highly complementary and help stabilize it. Radial and ulnar collateral ligaments prevent side-to-side movement of the forearm.
20. The wrist is composed of a condyloid joint between the distal end of the radius and the proximal carpals (scaphoid, lunate) that allows for flexion, extension, abduction, and adduction of the hand. The intercarpal joint between the proximal row of carpals and the distal row of carpals is a gliding joint allowing sliding movements between the carpals.
21. The hip joint is a ball-and-socket joint between the acetabulum of the hip bone and the head of the femur. It is adapted for weight bearing. Its articular surfaces are deep and secure, and its capsule is strongly reinforced by three ligamentous thickenings.
22. The knee is a complex and shallow joint formed by the articulation of the tibial and femoral condyles (and anteriorly by the patella with the femur). Extension, flexion, and some rotation are allowed. C-shaped menisci occur on the articular surfaces of the tibia. The capsule, which is absent anteriorly, is reinforced elsewhere by several capsular ligaments. For example, the tibial and fibular collateral ligaments help prevent hyperextension, abduction, and adduction of the leg. The intracapsular cruciate ligaments help prevent anterior-posterior displacement of the joint surfaces and

help lock the knee when one stands. The tone of the muscles crossing this joint is important for knee stability. In contact sports, lateral blows are responsible for many knee injuries. In noncontact sports, the anterior cruciate ligament is a frequent site of injury caused by quick stopping and change of direction.

23. The ankle joint is a hinge joint between (1) the distal tibia and fibula and (2) the talus of the foot. Its medial and lateral ligaments allow plantar flexion and dorsiflexion but prevent anterior and posterior displacements of the foot. Inversion and eversion of the foot occur through gliding movements at the intertarsal joints.

PAL Human Cadaver/Joints

Disorders of Joints (pp. 233–235)

Joint Injuries (p. 233)

24. Trauma can tear joint cartilages. Sports injuries to the knee menisci are common and can result from twisting forces as well as from direct blows to the knee. Arthroscopic surgery is used to repair knee and other joint injuries.
25. Sprains are the stretching and tearing of joint ligaments. Because ligaments are poorly vascularized, healing is slow.
26. Joint dislocations move the surfaces of articulating bones out of alignment. Such injuries must be reduced.

Inflammatory and Degenerative

Conditions (pp. 234–235)

27. Bursitis and tendinitis are inflammation of a bursa and a tendon sheath, respectively.
28. Arthritis is the inflammation or degeneration of joints accompanied by pain, swelling, and stiffness. Arthritis includes many different diseases and affects millions of people.
29. Osteoarthritis is a degenerative condition that first involves the articular cartilages. It follows wear or excessive loading, and is common in older people. Weight-bearing joints are most often affected.
30. Rheumatoid arthritis, the most crippling kind of arthritis, is an autoimmune disease involving severe inflammation of the joints, starting with the synovial membranes.
31. Gout is joint inflammation caused by a deposition of urate salts in the synovial membranes.

The Joints Throughout Life (p. 236)

32. Joints develop from mesenchyme between the cartilaginous “bone models” in the embryo.
33. Joints usually function well until late middle age, when osteoarthritis almost always appears.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Match the joint types in the key to the descriptions that apply to them (More than one joint type might apply.)

Key: (a) fibrous joints
(b) cartilaginous joints
(c) synovial joints

- (1) have no joint cavity
- (2) types are sutures and syndesmoses
- (3) dense connective tissue fills the space between the bones
- (4) almost all joints of the skull
- (5) types are synchondroses and symphyses
- (6) all are diarthroses
- (7) the most common type of joint in the body
- (8) nearly all are synarthrotic
- (9) shoulder, hip, knee, and elbow joints
2. Synovial joints have (a) articular cartilage, (b) a joint cavity, (c) a lubricant, (d) an articular capsule, (e) all of these.
3. In general, the most important factor(s) determining the stability of synovial joints is (a) interlocking shapes of the articular surfaces, (b) reinforcing ligaments, (c) ligaments and muscle tone, (d) synovial fluid, which acts like glue, (e) the body’s wrapping of skin, which holds the limbs together.
4. Characteristics of a symphysis include (a) presence of fibrocartilage, (b) ability to resist large compression and tension stresses, (c) presence of a joint cavity, (d) very high mobility, (e) both a and b.

5. Synovial joints are most richly innervated by nerve fibers that (a) monitor how much the capsule is stretched, (b) supply the articular cartilages, (c) cause the joint to move, (d) monitor pain when the capsule is injured.
6. Match the parts of a synovial joint listed in the key to their functions below. (More than one part may apply.)

Key: (a) articular cartilage (b) ligaments and fibrous capsule
(c) synovial fluid (d) muscle tendon

- (1) keeps bone ends from crushing when compressed; resilient
- (2) resists tension placed on joints
- (3) lubricant that minimizes friction and abrasion of joint surfaces
- (4) keeps joints from overheating
- (5) helps prevent dislocation
7. Indicate the joint (or joints) from the list in column B that contains the structure listed in column A.

Column A

- (1) medial meniscus
- (2) anular ligament
- (3) saddle joint
- (4) articular disc
- (5) rotator cuff
- (6) anterior cruciate ligament
- (7) deltoid ligament
- (8) ulnar collateral ligament
- (9) fibular collateral ligament

Column B

- (a) sternoclavicular joint
- (b) temporomandibular joint
- (c) wrist joint
- (d) shoulder joint
- (e) elbow joint
- (f) hip joint
- (g) knee joint
- (h) ankle joint

8. Classify each of the synovial joints listed as one of the following: (a) plane joint, (b) hinge joint, (c) pivot joint, (d) condyloid joint, (e) saddle joint, (f) ball-and-socket joint.
 - (1) proximal radioulnar joint
 - (2) trapezium and metacarpal 1
 - (3) knee (tibiofemoral)
 - (4) metacarpophalangeal joint
 - (5) wrist (radiocarpal) joint
 - (6) atlanto-occipital joint
 - (7) atlantoaxial joint
 - (8) sternocostal joints, ribs 2–7
 - (9) intervertebral joints (between articular processes)
 - (10) acromioclavicular
14. What are the functions of the menisci of the knee? Of the anterior and posterior cruciate ligaments?
15. Why are sprains and injuries to joint cartilages particularly troublesome?
16. Name the most common direction in which each of the following joints tends to dislocate: (a) shoulder, (b) elbow.
17. Examine the thorax using a skeleton or an illustration. Classify the various joints you see as containing either hyaline cartilage, fibrocartilage, or fibrous tissue (fibrous joints).
18. What are the technical names of and movements allowed at the following joints? (a) joints in the toes, (b) wrist joint, (c) jaw joint, (d) joint between sacrum and coxal bones, (e) knuckle joint in the hand.
19. List the functions of the following parts of a synovial joint: (a) fibrous part of the capsule, (b) synovial fluid, (c) articular disc.
20. Compare a bursa and a tendon sheath in terms of their structure, function, and locations.
21. Provide the anatomically proper names of the joints between (a) the scapula and clavicle, (b) the articular processes of successive vertebrae, (c) the ribs and sternum, (d) the ribs and vertebrae, (e) the various tarsal bones.
22. Name the joint that contains the (a) glenoid cavity and labrum; (b) cruciate ligaments and menisci; (c) anular ligament and head of radius; (d) coronoid process, trochlea, and radial collateral ligament; (e) medial and lateral ligaments and talus.

Short Answer Essay Questions

9. Define joint.
10. Where does synovial fluid come from?
11. Explain weeping lubrication of the synovial joint surfaces.
12. Compare and contrast (1) flexion and extension with (2) adduction and abduction.
13. Name two specific examples of each: hinge joint, plane joint, condyloid joint, ball-and-socket joint.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Harry was jogging down the road when he tripped in a pothole. As he fell, his ankle twisted violently to the side. The diagnosis was severe dislocation and spraining of the ankle. The surgeon stated that she would perform a reduction of the dislocation and then attempt to repair the injured ligament using arthroscopy. (a) What kinds of movements can normally occur at the ankle joint? (b) Was the doctor telling Harry that his bones were broken? (c) What is reduction of a joint? (d) Why is it necessary to repair ligaments surgically? (e) How will the use of arthroscopic surgery minimize Harry's recovery time and his suffering?
2. Dan Park, an exhausted anatomy student, was attending a lecture. After 30 minutes he began to doze. He woke up suddenly (the professor's voice was too loud to permit a good nap) and yawned widely. To his great distress, he couldn't close his mouth—his lower jaw was stuck open. What had happened?
3. Mrs. Estevez, who is 37 years old, visited her physician and complained of unbearable pain in several joints of both hands. The joints were very red, swollen, and warm to the touch. When asked if she had ever had such an episode in the past, she said she had had a similar attack 2 years earlier that had disappeared as suddenly as it had come. Her diagnosis was arthritis. (a) What type of arthritis does she have? (b) What is the cause of joint inflammation in this type of arthritis?
4. At work, a box fell from a shelf onto Ming's acromial region. In the emergency room, the physician could feel that the head of her humerus had moved into the axilla. What had happened to Ming?
5. At his ninety-fourth birthday party, Jim was complimented on how good he looked and was asked about his health. He answered, "I feel good, except that some of my joints ache and are stiff, especially my knees and hips and lower back, and especially when I wake up in the morning." A series of X-ray studies and an MRI scan taken a few weeks earlier showed that the articular cartilages of these joints were rough and flaking off and that bone spurs were present at the ends of some of Jim's bones. What is Jim's probable condition?
6. On the evening news, Samantha heard that the deer population in her state had increased greatly in the past few years, and she knew that deer were often seen walking the streets of her suburban community. Suddenly, she exclaimed, "So that's why several children in my son's class got Lyme disease this year!" Explain her reasoning. (See "Related Clinical Terms")
7. How does the structure of the joints in each limb reflect the function of each limb (mobility in the upper limb, stability in the lower limb)?



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10

Skeletal Muscle Tissue

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Muscle is from a Latin word meaning “little mouse,” a name given because flexing muscles look like mice scurrying beneath the skin. Indeed, the rippling skeletal muscles of weight lifters are often the first thing that comes to mind when one hears the word *muscle*. However, muscle is also the main tissue in the heart and in the walls of other hollow organs. Recall from Chapter 4 that muscle tissue is a composite tissue composed of muscle cells and surrounding connective tissues. In all its forms, muscle tissue makes up nearly half the body’s mass.

OVERVIEW OF MUSCLE TISSUE

- List four functional properties that distinguish muscle tissue from other tissues.
- Compare and contrast skeletal, cardiac, and smooth muscle tissue.

Contracted striated muscle fibers containing myelinated nerve fibers (colored TEM).



CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics of Chapter 10.

PAL = Human Anatomy Lab™

Overview of Muscle Tissue (pp. 240–241)

1. Muscle tissue produces movement, maintains posture, stabilizes joints, and generates body heat. It has the special properties of contractility, excitability, extensibility, and elasticity.
2. The three types of muscle tissue are skeletal, smooth, and cardiac muscle. Skeletal muscle attaches to the skeleton, has striated cells, and can be controlled voluntarily. Cardiac muscle occurs in the heart wall, has striated cells, and is controlled involuntarily. Smooth muscle occurs chiefly in the walls of hollow organs, has nonstriated cells, and is controlled involuntarily.
3. A cell in skeletal or smooth muscle (but not cardiac muscle) is called a fiber. A large percentage of the sarcoplasm of muscle cells is myofilaments that generate contractile force.

Skeletal Muscle (pp. 241–252)

Basic Features of a Skeletal Muscle (pp. 242–243)

4. Each skeletal muscle is an organ. The connective tissue elements of a skeletal muscle are the epimysium around the whole muscle, the perimysium around a fascicle, and the endomysium around fibers. A fascicle is a bundle of muscle fibers. All these connective tissue sheaths form the tendon.
5. Every skeletal muscle fiber is stimulated to contract by a nerve cell. Skeletal muscle has a rich blood supply. Fine nerve fibers and capillaries occupy the endomysium.
6. Each muscle extends from an immovable (or less movable) attachment, called the origin, to a more movable attachment, called an insertion.
7. Muscles attach to bones through tendons, aponeuroses, or direct (fleshy) attachments. Some muscles cross two or more joints.

Microscopic and Functional Anatomy of Skeletal Muscle Tissue (pp. 245–252)

8. A skeletal muscle fiber is a long, striated cell formed from the fusion of many embryonic cells. It contains many peripherally located nuclei.
9. Myofibrils are cylinder-shaped organelles that show distinct dark and light banding patterns, or striations. They are the main component of the sarcoplasm of skeletal muscle cells. A myofibril is a row of sarcomeres arranged end to end. A sarcomere extends from one Z disc to the next. Thin (actin) filaments extend centrally from each Z disc. Thick (myosin) filaments occupy the center of each sarcomere and overlap the inner ends of the thin filaments.
10. From large to small, the levels of organization in a muscle are whole muscle, fascicle, fiber, myofibril, sarcomere, and myofilament (see Table 10.1, p. 249).
11. The sarcoplasmic reticulum is a specialized smooth endoplasmic reticulum in the muscle fiber. T tubules are deep invaginations of the sarcolemma. When a nerve cell stimulates a muscle fiber, it sets up an impulse in the sarcolemma that signals the sarcoplasmic

reticulum to release Ca^{2+} , which then initiates the sliding of the myofilaments (muscle contraction).

12. Muscle contraction occurs by both concentric contraction, which shortens the muscle, and eccentric contraction, in which the muscle generates force while lengthening.
13. According to the sliding filament mechanism, concentric muscle contraction results when the thin filaments are pulled toward the center of the sarcomere by a pivoting action of myosin heads on the thick filaments.
14. The myofilaments determine the striation pattern in skeletal muscle fibers. There are A bands, where thick filaments are located; I bands, which contain only thin filaments; and Z discs, where thin filaments from adjacent sarcomeres join; plus M lines and H zones, where only thick filaments occur. During contraction, the Z discs move closer together, and the I bands and H zones shorten.
15. A muscle is extended, or stretched, by a skeletal movement caused by the contraction of an opposing muscle. The huge titin molecules in the sarcomere resist overextension, and, along with the connective tissue elements, give muscle its elasticity.
16. The muscles attach to the skeleton in a way that keeps them at a near-optimal length for generating maximum contractile forces.
17. Motor neurons innervate skeletal muscle fibers at neuromuscular junctions (motor end plates). The axon terminal releases acetylcholine, which signals the muscle cell to contract. The basal lamina of the muscle cell releases the enzyme acetylcholinesterase into the synaptic cleft, which breaks down acetylcholine immediately after the neurotransmitter signals a single contraction. Each muscle fiber must be served by a neuromuscular junction.
18. A motor unit consists of one motor neuron and all the skeletal muscle fibers it innervates. Motor units contain different numbers of muscle fibers distributed widely within a muscle. All muscle fibers in the motor unit contract simultaneously.
19. There are three types of skeletal muscle fibers: (1) slow oxidative fibers (fatigue resistant and best for maintaining posture), (2) fast glycolytic fibers (for short bursts of power), and (3) fast oxidative fibers (for long-term production of fairly strong contraction). Most muscles in the body contain a mixture of these fiber types.

PAL Histology/Muscular System

Disorders of Skeletal Muscle Tissue (p. 253)

20. The disorders discussed in this section include muscular dystrophy, myofascial pain syndrome, and fibromyalgia.

Skeletal Muscle Tissue Throughout Life (pp. 255–257)

21. Muscle tissue develops from embryonic mesoderm cells called myoblasts. Skeletal muscle fibers form by the fusion of many myoblasts.
22. Mature skeletal muscle tissue has some ability to regenerate because of its satellite cells.
23. On the average, men have more muscle mass than women. This disparity is due to the effects of male sex hormones.
24. Skeletal muscles are richly vascularized and resistant to infection, but in old age they shrink, become fibrous, and lose strength. This condition, called sarcopenia, is reversible through exercise.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- The connective tissue that lies just outside the sarcolemma of an individual muscle cell is called the (a) epimysium, (b) perimysium, (c) endomysium, (d) endosteum.
- A fascicle is (a) a muscle, (b) a bundle of muscle cells enclosed by a connective tissue sheath, (c) a bundle of myofibrils, (d) a group of myofilaments.
- Thick and thin myofilaments have different properties. For each phrase below, indicate whether the filament described is thick or thin (write *thick* or *thin* in the blanks).
 - _____ (1) contains actin
 - _____ (2) contains myosin heads
 - _____ (3) contains myosin
 - _____ (4) does not lie in the H zone
 - _____ (5) does not lie in the I band
 - _____ (6) attaches to a Z disc
- Write *yes* or *no* in each blank below to indicate whether each of the following narrows when a skeletal muscle fiber contracts.
 - _____ (1) H band
 - _____ (2) A band
 - _____ (3) I band
 - _____ (4) M line
- Match the level of skeletal muscle organization given in the key with its description:

Key:

- | | | |
|---------------|-----------------|-----------|
| (a) muscle | (b) fascicle | (c) fiber |
| (d) myofibril | (e) myofilament | |

- _____ (1) rod-shaped organelle; made of sarcomeres
 - _____ (2) an organ
 - _____ (3) a bundle of cells
 - _____ (4) a group of large molecules
 - _____ (5) a cell
- The function of T tubules in muscle contraction is to (a) make and store glycogen, (b) release Ca^{2+} into the cell interior and then pick it up again, (c) transmit an impulse deep into the muscle cell, (d) make proteins.
 - Which fiber type would be the most useful in the leg muscles of a long-distance runner? (a) fast glycolytic, (b) slow glycolytic, (c) fast oxidative.

- The ions that first enter a muscle cell when an impulse passes over its sarcolemma and then trigger muscle contraction are (a) calcium, (b) chloride, (c) sodium, (d) potassium.
- Fill in each blank with the correct answer from the key. More than one answer may be correct.

Key:

- | | | |
|---------------------|--------------------|-------------------|
| (a) skeletal muscle | (b) cardiac muscle | (c) smooth muscle |
|---------------------|--------------------|-------------------|
- _____ (1) striated and involuntary
 - _____ (2) striated and voluntary
 - _____ (3) not striated and involuntary
 - _____ (4) is present in wall of bladder
 - _____ (5) is located only in the heart
 - _____ (6) its fibers are giant, multinucleate cells
 - _____ (7) the individual muscle cells are called muscle fibers
 - _____ (8) has no A or I bands
 - _____ (9) it is located in the walls of hollow body organs
 - _____ (10) its extranuclear materials are called sarcoplasm instead of cytoplasm, and the plasma membrane is called the sarcolemma

Short Answer Essay Questions

- Name and explain the four special functional characteristics of muscle tissue.
- (a) Distinguish a tendon from an aponeurosis and a fleshy attachment. (b) Define origin and insertion, and explain how they differ.
- Explain the sliding filament theory of contraction by drawing and labeling a relaxed and a contracted sarcomere.
- Define motor unit.
- List the structural differences between the three distinct types of skeletal muscle fibers.
- Cindy Wong was a good anatomy student, but she realized she was mixing up the following “sound-alike” structures in skeletal muscle: myofilaments, myofibrils, fibers, and fascicles. Therefore, she compiled a brief table to define and differentiate these four structures. Construct a table like hers.
- What is the function of the sarcoplasmic reticulum in a skeletal muscle cell?
- Define sarcolemma and sarcoplasm.
- Where is titin located, and what are its functions?
- What is the general distribution of skeletal muscle fiber types in various body regions (trunk, upper limb, lower limb) and how is fiber type related to function of that body region?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. A certain anatomy student decided that his physique left much to be desired. He joined a health club and began to “pump iron” three times a week. After 3 months of training, during which he was able to lift increasingly heavy weights, his arm and chest muscles became much larger. Explain what happened to the fibers in these muscles.
2. Diego, who had not kept in shape, went out to play a game of touch football. As he was running, the calf region of his leg began to hurt. The next day he went to a doctor, who told him he had a strain. Diego kept insisting that no joints hurt. Clearly, he was confusing a *strain* with a *sprain*. Explain the difference.
3. Chickens are capable of only brief bursts of flight, and their flying muscles consist of fast glycolytic fibers. The breast muscles of ducks, by contrast, consist of slow and fast oxidative fibers. What can you deduce about the flying abilities of ducks?
4. Takashi, an osteopathic physician, saw that Mrs. and Mr. Rogers were suffering because their son was fighting a long battle with Duchenne muscular dystrophy. To comfort them, Takashi said that one day physicians hope to be able to cure this disease by injecting healthy myoblasts into the weakened muscles. What are myoblasts?
5. Why are muscle infections relatively rare (compared to respiratory or skin infections, for example)?
6. As a sprinter, Lateesha knew that the best way to treat pulled muscles was through “RICE” (see Chapter 9, p. 231). What does that mean?
7. After her first day of skiing for the season, Janine woke up with stiff, achy muscles. What caused the sore muscles, and should Janine head out to the slopes for a second day of skiing?
8. Given what you have learned about increasing muscle strength through weight training, why do athletes taper off their training regimen prior to a major competitive event?
9. Skeletal muscle cells cannot divide. How does skeletal muscle repair itself when injured?



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Muscles of the Body

11

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Musculature of the lower limb (MRI).

sprinters who tense the tendon too severely while starting a race. The rupture leads to a gap just superior to the heel, and the calf bulges as the triceps surae muscles are released from their insertion. As a result, plantar flexion is very weak, but dorsiflexion is exaggerated. The tendon must be repaired surgically.

CHAPTER SUMMARY

You can use the following media study tool for additional help as you review specific key topics in Chapter 11.

PAL = Human Anatomy Lab™

Arrangement of Fascicles in Muscles (pp. 262–263)

1. For a summary of fascicle arrangements, see Figure 11.1.

Lever Systems: Bone-Muscle Relationships (pp. 263–265)

2. A lever is a rigid bar that moves on a fulcrum. When an effort is applied to the lever, a load is moved. In the body, bones are the levers, joints are the fulcrums, and the effort is exerted by skeletal muscles pulling on their insertions.
3. When the effort is farther from the fulcrum than is the load, the lever works at a mechanical advantage, a power lever. When the effort is closer to the fulcrum than is the load, the lever works at a mechanical disadvantage, a speed lever.
4. First-class levers (fulcrum located between load and effort) may operate at a mechanical advantage or disadvantage. Second-class levers (load between fulcrum and effort) all work at a mechanical advantage. Third-class levers (effort between fulcrum and load) all work at a mechanical disadvantage. Most muscles of the body are in third-class lever systems and therefore provide speed of movement.

Organizational Scheme Based on Embryonic Development (pp. 265–267)

5. Based on embryonic origin and general functions, the muscles of the body can be divided into four main groups: visceral muscle, pharyngeal arch muscles, axial muscles, and limb muscles.
6. *Pharyngeal arch muscles* are skeletal muscles that develop from somitomeres and surround the pharynx, but some migrate into the head and back during development. The *axial muscles* of the neck and trunk derive from myotomes. They include dorsal muscles that extend the spine and ventral muscles that flex the spine. Of the axial muscles in the head, the eye muscles and the tongue muscles develop from somitomeres and occipital myotomes, respectively. *Limb muscles* derive from the ventral-lateral portions of myotomes and exhibit the same arrangement in the upper and lower limbs: extensors on one side, flexors on the other.

Muscle Actions and Interactions (pp. 267–269)

7. Skeletal muscles are arranged in opposing groups across movable joints such that one group can reverse or modify the action of the other.
8. Prime movers (agonists) bear the main responsibility for a particular movement. Antagonists produce the opposite movement. Synergists help the prime movers, prevent undesirable movements, or stabilize joints (as fixators).
9. Muscles that cross on the anterior side of a joint generally produce flexion. Those that cross the joint posteriorly generally are extensors. Adductors cross on the medial side of a joint, and abductors cross on the lateral side.

SHIN SPLINTS Common term for pain in the anterior leg caused by swelling of the tibialis anterior muscle. This muscle swells after heavy exercise in the absence of adequate prior conditioning. Because it is tightly wrapped by fascia, the tibialis anterior cuts off its own circulation as it swells and presses painfully on its own nerves.

Muscle Compartments of the Limbs (pp. 269–274)

10. The muscles of the limbs are organized into compartments: anterior (flexor) and posterior (extensor) compartments in the arm and the forearm; posterior, anterior, and medial compartments in the thigh; and posterior, anterior, and lateral compartments in the leg. Muscles located in the same compartment generally have similar function and innervation. Summary tables of the muscles of the upper and lower limbs (Tables 11.1 and 11.2) provide an excellent review of muscle actions, interactions, and compartments.

Naming the Skeletal Muscles (pp. 274–275)

11. Muscles are named for their location, shape, relative size, fascicle direction, location of attachments, number of origins, and action.

Major Skeletal Muscles of the Body (pp. 275–330)

12. The muscles are divided into functional groups and presented in detail in Tables 11.3 through 11.17. The muscles of facial expression (Table 11.3) are thin and insert primarily on the facial skin. They close the eyes and lips, compress the cheeks, and allow people to smile and show feelings.
13. Chewing muscles include the masseter and temporalis that elevate the mandible and the two pterygoids that assist in grinding food. Extrinsic muscles of the tongue anchor the tongue and control its movements (Table 11.4).
14. Deep muscles in the anterior neck aid swallowing by lifting and then depressing the larynx (suprahyoid and infrahyoid groups). Pharyngeal constrictors squeeze food into the esophagus (Table 11.5).
15. Muscles moving the head and muscles extending the spine are described in Table 11.6. Flexion and rotation of the head and neck are brought about by the sternocleidomastoid and scalenes in the anterior and lateral neck. Extension of the spine and head is brought about by deep muscles of the back and the posterior neck (for example, the erector spinae and splenius muscles).

PAL Human Cadaver/Muscular System/Head and Neck

16. Movements of breathing are promoted by the diaphragm and by the intercostal muscles of the thorax (Table 11.7). Contraction of the diaphragm increases abdominal pressure during straining, an action that is aided by the muscles of the abdominal wall.
17. The sheetlike muscles of the anterior and lateral abdominal wall (Table 11.8) are layered like plywood. This layering forms a strong wall that protects, supports, and compresses the abdominal contents. These muscles can also flex the trunk.
18. Muscles of the pelvic floor and perineum (Table 11.9) support the pelvic organs, inhibit urination and defecation, and aid erection.
19. The superficial muscles of the thorax attach to the pectoral girdle and fix or move the scapula during arm movements (Table 11.10).

PAL Human Cadaver/Muscular System/Trunk

20. The muscles that move the arm at the shoulder joint originate from the shoulder girdle (Table 11.11) or from the axial skeleton. Four muscles form the musculotendinous rotator cuff, which stabilizes the shoulder joint. As a rule, muscles located on the anterior thorax flex the arm (pectoralis major), whereas the posterior muscles extend it (latissimus dorsi). Abduction is mostly brought about by the deltoid. Adduction and rotation are brought about by many muscles on both the anterior and posterior sides.
21. Most muscles in the arm move the forearm (Table 11.12). Anterior arm muscles are flexors of the forearm (biceps, brachialis), and posterior arm muscles are extensors of the forearm (triceps).
22. Forearm muscles primarily move the hand (Table 11.13). Anterior forearm muscles flex the hand and fingers (but include two pronators), whereas the posterior muscles are mostly extensors (but include the strong supinator).
23. The intrinsic muscles of the hand allow for fine movements of the fingers (Table 11.14) and opposition, which aid in gripping objects in the palms. These small muscles are divided into thenar, hypothenar, and midpalmar groups.

PAL Human Cadaver/Muscular System/Upper Limb

24. Muscles that bridge the hip and knee joints move the thigh and the leg (Table 11.15). Anterior muscles mostly flex the thigh and extend the leg (quadriceps femoris), medial muscles adduct the thigh (adductors), and posterior muscles (gluteals, hamstrings) primarily abduct and extend the thigh and flex the leg.
25. Muscles in the leg act on the ankle and toes (Table 11.16). Leg muscles in the anterior compartment are mostly dorsiflexors of the foot (extensor group). Muscles in the lateral compartment are everters and plantar flexors of the foot (fibular group), and posterior leg muscles are strong plantar flexors (gastrocnemius and soleus, flexor group).
26. The intrinsic muscles of the foot (Table 11.17) support the foot arches and help move the toes. Most occur in the sole, arranged in four layers. They resemble the small muscles in the palm of the hand.

PAL Human Cadaver/Muscular System/Lower Limb and Muscular System/All Regions**Regional Surface Anatomy (pp. 329–341)**

27. Surface anatomy, the study of the surface landmarks and their relationship to internal organs, is an excellent tool for reviewing and reinforcing the skeletal and muscular anatomy you are learning. Identifying surface landmarks via palpation is an important clinical skill for assessing structure and function.

The Head (pp. 330–331)

28. In the cranium, the bony and muscular structures that can be felt through the skin include the superciliary arches, external occipital protuberance, superior nuchal line, mastoid process, temporalis muscles, and epicranium muscle.
29. The scalp covers the superior surface of the cranium and consists of skin, a highly vascular subcutaneous layer, and the galea aponeurotica.
30. The face is divided into orbital, nasal, auricular, and oral regions. The bony parts of the nose are the root and the bridge. The two principal parts of the auricle are its helix and lobule.

31. Palpable features of the face include the zygomatic arch, the mandibular body, and the mandibular ramus, masseter muscle, and temporomandibular joint in the oral region.

The Neck (pp. 331–332)

32. By running a finger inferiorly along the anterior midline of the neck, you can palpate the hyoid bone, laryngeal prominence, and cricoid cartilage.
33. The sternocleidomastoid muscle is an important surface landmark of the neck. The large trapezius muscle is located on the posterior aspect of the neck.
34. The posterior triangle of the neck is defined by the sternocleidomastoid anteriorly, the trapezius posteriorly, and the clavicle inferiorly. The anterior triangle is defined by the inferior margin of the mandible superiorly, the midline of the neck anteriorly, and the sternocleidomastoid posteriorly.

The Thorax (p. 332)

35. The sternal angle is an important surface landmark on the anterior thorax. By finding the second rib at the sternal angle, you can count inferiorly to identify the other ribs. The midaxillary and mid-clavicular lines are imaginary vertical lines that extend inferiorly from the center of the axilla and clavicle, respectively. The apex of the inverted V-shaped costal margin (infrasternal angle) is at the xiphisternal joint.

The Abdomen (pp. 333–334)

36. Surface landmarks on the anterior abdominal wall include the iliac crest, anterior superior iliac spine, groove for the inguinal ligament, pubic tubercle, pubic crest, pubic symphysis, umbilicus, groove for linea alba, rectus abdominis muscle, linea semilunaris, and external oblique muscle.

The Back (pp. 334–335)

36. In the posterior median furrow of the back, you can count and identify the vertebral spinous processes. The most easily located vertebral spines are C7 and T1 (the most prominent spines). Also palpable are T3 (at the level of the medial end of the spine of the scapula), T7 (at the level of the inferior scapular angle), and L4 (at the level of the supracristal line).
38. Superficial muscles of the back include the trapezius and latissimus dorsi, which, along with the medial border of the scapula, define the triangle of auscultation. The deeper erector spinae muscles flank the vertebral column.

The Upper Limb and Shoulder (pp. 335–338)

39. Important superficial structures associated with the axilla include the base of the axilla and the anterior and posterior axillary folds.
40. Skeletal landmarks that can be palpated in the shoulder region include the acromion of the scapula, clavicle, acromioclavicular joint, and the greater tubercle of the humerus.
41. The principal muscle of the shoulder is the deltoid muscle.
42. On the arm, you can palpate the humerus and the biceps and triceps brachii muscles. The medial bicipital furrow (groove) is located on the medial side of the arm.
43. Bony landmarks in the elbow region include the two epicondyles of the humerus and the olecranon process of the ulna, all lying in the same horizontal plane.

44. The cubital fossa is the triangular depression on the anterior surface of the elbow region bounded laterally by the brachioradialis and pronator teres muscles.
45. In the forearm, the palpable bony structures include the entire posterior margin of the ulna and the distal half and head of the radius. At the wrist, the styloid process of the radius lies distal to the styloid process of the ulna.
46. One can palpate the flexor and extensor muscle groups on the anterior and posterior forearm, respectively.
47. On the anterior forearm near the wrist are the tendons of the flexor carpi radialis, palmaris longus (absent in some people), and flexor carpi ulnaris.
48. The tendons of the thumb extensor muscles define the anatomical snuff box on the posterior base of the thumb. The styloid process of the radius and the scaphoid bone are located here.

The Lower Limb and Gluteal Region (pp. 338–341)

49. The posterior point of the iliac crest is the posterior superior iliac spine, which is represented by a dimple in the skin and indicates the location of the sacroiliac joint. Other bony landmarks in the gluteal region are the ischial tuberosities and the greater trochanter of the femur.
50. The right and left gluteal prominences, separated by the natal cleft, consist of gluteus maximus muscles and subcutaneous fatty tissue.

The gluteal fold is the inferior margin of the gluteus maximus. The ischial tuberosities support body weight during sitting.

51. The main groups of thigh muscles are the quadriceps femoris muscles, the adductor muscles, and the hamstrings. Bony landmarks that can be palpated in the thigh include the patella and the condyles of the femur.
52. The femoral triangle on the anterior superior thigh is formed by the inguinal ligament superiorly and by the sartorius and adductor longus muscles laterally.
53. The popliteal fossa is a diamond-shaped hollow on the posterior aspect of the knee, defined by four muscular boundaries: biceps femoris, semitendinosus, semimembranosus, and gastrocnemius.
54. Bony landmarks that can be palpated in the leg include the tibial tuberosity and tibial condyles, the anterior border and medial surface of the tibia, the head of the fibula, and the lateral and medial malleolus.
55. The main muscles of the leg, which can be palpated as they contract, are the gastrocnemius and soleus on the calf, the muscles in the anterior compartment, and the fibularis muscles on the fibula.
56. On the dorsum of the foot, one can observe the dorsal venous arch and the tendons of the extensor digitorum longus and extensor hallucis longus muscles.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. A muscle whose fascicles are arranged at an angle to a central longitudinal tendon has this arrangement: (a) circular, (b) longitudinal, (c) parallel, (d) pennate, (e) convergent.
2. A muscle that helps an agonist by causing a similar movement or by stabilizing a joint over which the agonist acts is (a) an antagonist, (b) a prime mover, (c) a synergist, (d) a fulcrum.
3. Match the muscles in column B to their embryonic origins in column A.

Column A

- (1) from head (occipital) myotomes
- (2) from trunk (nonlimb) myotomes
- (3) limb extensor group
- (4) limb flexor group
- (5) pharyngeal arch muscles

Column B

- (a) biceps brachii
- (b) erector spinae
- (c) tongue muscles
- (d) chewing muscles
- (e) triceps brachii

4. The muscle that closes the eyes is (a) the occipitalis, (b) the zygomaticus, (c) the corrugator supercilii, (d) the orbicularis oris, (e) none of these.
5. The arm muscle that flexes the forearm at the elbow and supinates it is the (a) brachialis, (b) brachioradialis, (c) biceps brachii, (d) triceps brachii.

6. The chewing muscles that protract the mandible and grind the teeth from side to side are (a) the buccinators, (b) the masseters, (c) the temporalis, (d) the pterygoids, (e) none of these.
7. Muscles that depress the hyoid bone and larynx include all of the following *except* the (a) sternohyoid, (b) omohyoid, (c) geniohyoid, (d) sternothyroid.
8. The quadriceps femoris muscles include all of the following except the (a) vastus lateralis, (b) biceps femoris, (c) vastus intermedius, (d) rectus femoris.
9. A prime mover of thigh flexion at the hip is the (a) rectus femoris, (b) iliopsoas, (c) vastus intermedius, (d) gluteus maximus.
10. Someone who sticks out a thumb to hitch a ride is _____ the thumb. (a) extending, (b) abducting, (c) adducting, (d) opposing.
11. The major muscles used in doing a chin-up are the (a) triceps brachii and pectoralis major, (b) infraspinatus and biceps brachii, (c) serratus anterior and external oblique, (d) latissimus dorsi and brachialis.
12. The anatomical snuff box (a) is in the nose, (b) contains the styloid process of the radius, (c) is defined by tendons of the flexor carpi radialis and palmaris longus, (d) is on the ventral side of the hand.
13. A muscle that contributes to the posterior axillary fold is the (a) pectoralis major, (b) latissimus dorsi, (c) trapezius, (d) infraspinatus, (e) pectoralis minor.

Short Answer Essay Questions

14. Define and distinguish first-, second-, and third-class levers. Which types of levers operate at a mechanical advantage?
15. (a) Name the four pairs of muscles that act together to compress the abdominal contents. (b) How do their fiber (fascicle) directions contribute to the strength of the abdominal wall? (c) Of these four muscles, which is the strongest flexor of the vertebral column? (d) Name the prime mover of inhalation (inspiration) in breathing.
16. List all six possible movements of the humerus that can occur at the shoulder joint, and name the prime mover(s) of each movement.
17. (a) Name two forearm muscles that are both powerful extensors and abductors of the hand at the wrist. (b) Name the only forearm muscle that can flex the distal interphalangeal joints. (c) Name the hand muscles responsible for opposition.
18. (a) Name the lateral rotators of the hip. (b) Explain the main function of each of the three gluteal muscles.
19. What is the functional reason why the muscle group on the dorsal leg (calf) is so much larger than the muscle group in the ventral region of the leg?
20. Define (a) a fascia compartment in a limb and (b) a retinaculum in a limb.
21. Name two muscles in each of the following compartments or regions: (a) thenar eminence (ball of thumb), (b) posterior compartment of forearm, (c) anterior compartment of forearm—deep muscle group, (d) anterior muscle group in the arm, (e) muscles of mastication, (f) third muscle layer of the foot, (g) posterior compartment of leg, (h) medial compartment of thigh, (i) posterior compartment of thigh.
22. (a) What muscles develop from the embryonic structures called somitomeres? (b) What are the major groups of pharyngeal arch (branchiomic) muscles? (c) What three constrictor muscles squeeze swallowed food through the pharynx to the esophagus?
23. Describe the location and function of the levator ani muscle.
24. Deduce some characteristics of the following muscles based on their names: tibialis anterior; temporalis; erector spinae.
25. For the following muscles, list one action of each, one muscle that acts as an antagonist, and one muscle that functions as a synergist: pectoralis major; biceps femoris; flexor carpi ulnaris; adductor magnus; rectus abdominis.
26. (a) Define palpation. (b) Why is a knowledge of surface anatomy valuable in clinical situations and for evaluating athletic injuries?
27. Explain how one locates the proper site for intramuscular injections into (a) the ventral gluteal site and (b) the deltoid muscle.
28. Esperanza, a pre-physical therapy student, was trying to locate the vertebral spinous processes on the flexed back of her friend Chao, but she kept losing count. Chao told her to check her count against several reliable “guideposts” along the way: the spinous processes of C₇, T₃, T₇, and L₄. Describe how to find each of these four vertebrae without having to count any vertebrae.
29. Name the borders of the triangle of auscultation.
30. Tell where to locate the following thigh structures: (a) greater trochanter of the femur, (b) adductor muscles, (c) vastus lateralis, (d) bony origin of the hamstring muscles.

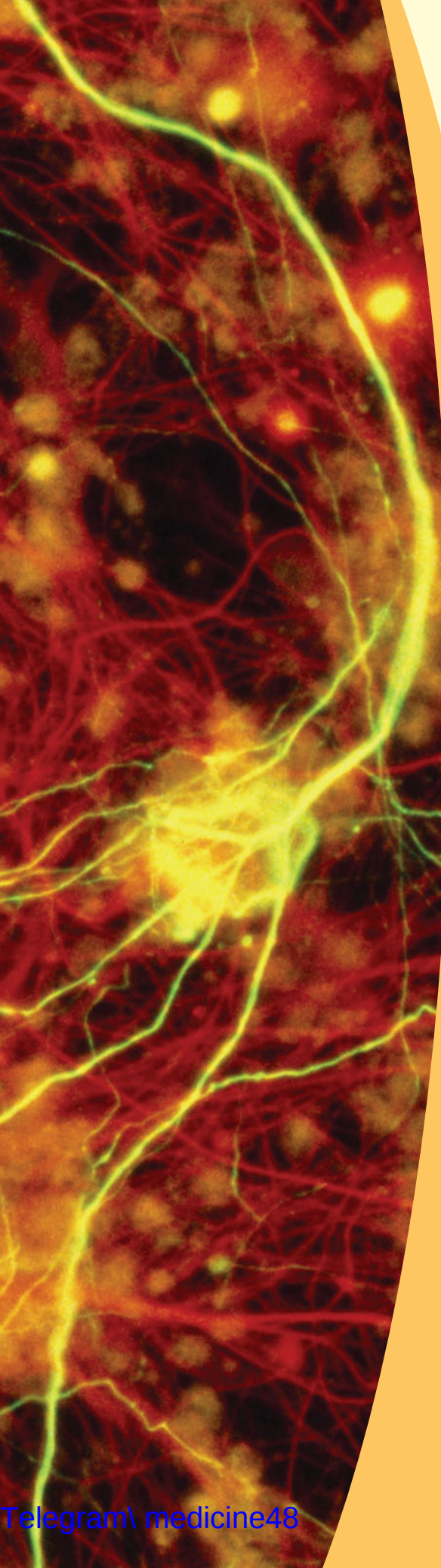
CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Rosario, a student nurse, was giving Mr. Graves a back rub. What two broad superficial muscles of his back were receiving most of her attention?
2. When Mrs. O'Brian returned to her doctor for a follow-up visit after childbirth, she complained that she was having problems controlling urine flow (was incontinent) when she sneezed. The physician gave Mrs. O'Brian instructions in performing exercises to strengthen the muscles of the pelvic floor. What are these specific muscles?
3. Assume you are trying to lift a heavy weight off the ground with your right hand. Explain why it will be easier to flex your forearm at the elbow when your forearm is supinated than when it is pronated.
4. Chao-Jung abducted her thigh very strongly while riding a horse and pulled some groin muscles in her medial upper thigh. What muscles did she probably strain, and what is the medical name for her condition? (Hint: See this chapter's Related Clinical Terms.)
5. When bodybuilders develop the muscles on one side of a limb more than on the other side, they are said to be “muscle bound.” Describe the symptoms of this condition, and explain how they are produced.
6. Based on its fascicle orientation, determine whether each of the following muscles is built for large range of movement or for power: sartorius; rectus femoris; latissimus dorsi; subscapularis; gluteus maximus.
7. A baseball pitcher injured a rotator cuff muscle. When he abducts and laterally rotates his shoulder, it dislocates anteriorly. What muscle is injured and thus making the joint unstable?

8. What class of lever is described by the following activities: (1) the soleus plantar flexing the foot; (2) the deltoid abducting the arm; (3) the triceps brachii extending the forearm during push-ups?
9. Walking to her car after her 65th birthday party, Mrs. Schultz tripped on ice and fell forward on her outstretched palms. When she arrived at the emergency room, her right wrist and hand were bent like a fork. Dr. Jefferson felt that the styloid process of her radius was outside of the anatomical snuff box and slightly proximal to the styloid process of the ulna. When he checked her elbow, he found that the olecranon process lay 2 cm proximal to the two epicondyles of the right humerus. Explain all these observations, and describe what had happened to Mrs. Schultz's limb.
10. An athletic trainer was examining a college basketball player to find the site of a pulled muscle. The trainer asked the athlete to extend her thigh forcefully at the hip, but she found this action too painful to perform. Then the trainer palpated her posterior thigh and felt some swelling of the muscles there. In the simplest terms, which basic muscle group was injured?



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Fundamentals of the Nervous System and Nervous Tissue

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◀ *Branching nerve fiber and astrocyte cells from the mammalian cortex
(immunofluorescent light micrograph 2000×).*

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Which of the following structures is *not* part of the central nervous system? (a) the brain (b) a nerve (c) the spinal cord (d) a tract
- Match the names of the cells in column B with the function they perform, shown in column A.

Column A

- ____ (1) form myelin in the CNS
- ____ (2) line the central cavity of the brain
- ____ (3) form myelin in the PNS
- ____ (4) CNS phagocytes
- ____ (5) regulate ionic composition of the fluid around neurons in the CNS
- ____ (6) remove neurotransmitters in the CNS

Column B

- (a) astrocytes
- (b) ependymal cells
- (c) microglia
- (d) oligodendrocytes
- (e) satellite cells
- (f) Schwann cells

- Which of the following structures is in the somatic part of the human body? (a) bladder, (b) biceps muscle, (c) lung, (d) stomach.
- Classify the following inputs and outputs as either somatic sensory (SS), visceral sensory (VS), somatic motor (SM), or visceral motor (VM).
 - ____ (1) pain from skin
 - ____ (2) taste
 - ____ (3) efferent innervation of a gland
 - ____ (4) efferent innervation of the gluteus maximus
 - ____ (5) a stomachache
 - ____ (6) a sound one hears
 - ____ (7) efferent innervation of the masseter
- An example of an effector is (a) the eye, (b) a gland, (c) a sensory neuron, (d) a motor neuron.
- Which of the following parts of a neuron occupies the gray matter in the spinal cord? (a) tracts of long axons, (b) motor neuron cell bodies, (c) sensory neuron cell bodies, (d) nerves.
- A ganglion is a collection of (a) neuron cell bodies, (b) axons of motor neurons, (c) interneuron cell bodies, (d) axons of sensory neurons.
- A synapse between an axon terminal and a neuron cell body is classified as (a) axodendritic, (b) axoaxonic, (c) axosomatic, (d) axoneuronic.
- Myelin is most like which of the following cell parts introduced in Chapter 2? (a) the cell nucleus, (b) smooth endoplasmic reticulum, (c) ribosomes, (d) the plasma membrane.

- Match the following parts of the adult nervous system with the embryonic cells that give rise to them: (a) alar plate cells, (b) basal plate cells, (c) neural crest cells.
 - ____ (1) sensory neurons
 - ____ (2) motor neurons
 - ____ (3) dorsal interneurons

- Afferent neurons of the PNS synapse in the CNS with (a) axons in the white matter, (b) neuron cell bodies in the gray matter, (c) neuron cell bodies in the white matter, (d) axons in the gray matter.
- A monosynaptic reflex is an example of (a) a convergent circuit, (b) parallel processing, (c) serial processing, (d) a reverberating circuit.
- Most nerves are composed of (a) afferent neurons only, (b) efferent neurons only, (c) dendrites, (d) axons of afferent and efferent neurons, (e) neuron cell bodies and neuroglia.
- Place the connective tissue coverings surrounding a nerve in order from superficial (1) to deep (3).
 - ____ perineurium ____ epineurium ____ endoneurium

Short Answer Essay Questions

- Define proprioception.
- Sin Young incorrectly classified proprioception as general somatic *motor* because it refers to the innervation of muscles. Actually, proprioception is general somatic *sensory*. Explain why.
- Define interneuron.
- Distinguish gray matter from white matter of the CNS in terms of location and composition.
- Describe the appearance of a cell nucleus of a neuron.
- Describe the differences between neurons and neuroglia in terms of structure, function, and location.
- Distinguish a nerve from a nerve fiber and a neuron.
- Explain why damage to peripheral nerve fibers is often reversible, whereas damage to CNS fibers rarely is.
- Draw a reflex arc in place in the nervous system (recall Figure 12.11). Would the reflex still function if the neurons in the sensory ganglia were destroyed?
- Define axon and dendrite.
- Why are the cell bodies of sensory neurons located outside the CNS?
- Describe the relationship between axons and Schwann cells in myelinated versus unmyelinated nerve fibers.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

- Two anatomists were arguing about a sensory neuron. One anatomist said its peripheral process is an axon and gave two good reasons, but the other called the peripheral process a dendrite and also gave a good reason. Cite all three reasons given, and state your own opinion.
- A CT scan and other diagnostic tests indicated that Laressa had developed an oligodendroglioma. Can you deduce from its name what an oligodendroglioma is?
- The following event received worldwide attention in 1962: A boy playing in a train yard fell under a train, and his right arm was cut off cleanly by the wheels. Surgeons reattached the arm, sewing nerves and vessels back together. The surgery proceeded very well. The arm immediately regained its blood supply, yet the boy could not move the limb or feel anything in it for months. Explain why it took longer to reestablish innervation than circulation.
- Rochelle developed multiple sclerosis when she was 27. After 8 years she had lost a good portion of her ability to control her skeletal muscles. Explain how this happened.
- Reflexes can be somatic (as in the knee jerk response) or visceral (as in vomiting). Given that both result in an involuntary motor response, why aren't they both considered visceral motor?
- A peripheral nerve that is damaged can regenerate after a period of time (6–12 months), such that its function is renewed. Damage to the spinal cord is a permanent injury. Why such different prognoses for these two injuries?



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The Central Nervous System

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Postnatal Changes in the Brain 420



Section through the cerebellum (light micrograph 5X)

Maturation of the nervous system continues through childhood and reflects the progressive myelination and thickening of its axons.

Despite the great plasticity of young brains, there are critical periods after which learning is no longer possible. For example, no one has ever learned a first language after about age 5, and childhood abuse can so greatly retard the maturation of the frontal lobes that normal cognitive functioning is not attained. Recent studies suggest these critical periods are not as rigid as once was believed, providing more hope for deprived children.

Formerly it was thought that the brain's circuitry is fully formed by late childhood, but new findings show that such maturation is not complete until people are in their early 20s. In teenagers, the "rational" frontal lobe is still organizing itself at the same time that "emotional" limbic structures are in developmental overdrive from the effects of sex hormones. This may explain why some teenagers seem moody or abandon good judgment for risky, thrill-seeking behaviors.

The brain reaches its maximum weight in the young adult, but with age it shrinks, and its cognitive abilities slowly decline. Traditionally, this decline has been attributed to neuronal death, but improved techniques now suggest that the

number of brain neurons does not decrease with age—at least in the cerebral cortex and hippocampus. The reason for declining brain function with age may instead lie in changes in neural circuitry or in lower amounts of neurotransmitters being released at synapses. Studies show that the elderly compensate for this decline by using more regions of the cerebral cortex and that keeping mentally active can slow the rate of brain shrinkage. Finally, the choroid plexus calcifies in the elderly, drastically reducing the production of cerebrospinal fluid late in life.

check your understanding

30. Individuals who have suffered a stroke generally have functional deficits on the side of the body opposite from the injured brain tissue. Explain this in reference to your knowledge of ascending and descending pathways in the CNS.
31. Which regions of the cerebral cortex are active in a newborn baby? Which region of the cortex is not fully developed until early adulthood?

For answers, see Appendix B.

RELATED CLINICAL TERMS

ENCEPHALOPATHY (en-sef'ah-lop'ah-the) Any disease or disorder of the brain.

MICROCEPHALY (mi'kro-sef'ah-le) Congenital condition involving the formation of a small brain and skull. May result from damage to the brain before birth or from premature fusion of the sutures of the skull. Most microcephalic children have severe mental deficits.

MYELITIS (mi'ē-li-tis; *myel* = spinal cord) Inflammation of the spinal cord.

MYELOGRAM (*gram* = recording) X-ray study of the spinal cord after injection of a contrast medium.

PHANTOM LIMB PAIN People who have had a limb amputated commonly perceive pain in the "phantom" body part that is no longer present. Although it can be spontaneous, the pain is often induced by touching the skin of the limb stump or the face. The cause of this

pain is now understood. First, the amputation removes all axonal input to the limb representation on the primary somatosensory cerebral cortex. Next, this denervated cortical area is reinnervated by growing axons from the nearby cortical regions that contain face and stump representations, such that touches on the face and stump are interpreted as coming from the now-missing limb.

TOURETTE'S SYNDROME A brain disorder that affects about 1 of every 3000 Americans, mostly males. Characterized by tics (sudden, fast movements or sounds) such as blinks, grimaces, barks, and yelps. May involve obscene vocalizations, repeating the words and actions of others, and obsessive-compulsive behavior. In this condition, the basal ganglia do not properly regulate a neurotransmitter called dopamine and thus cannot interact with the motor cerebral cortex to inhibit stereotypical behaviors. This syndrome is treated with psychotropic drugs. After the preteen years, the severity of the symptoms usually declines with age.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 13.

PAL = Practice Anatomy Lab™

The Spinal Cord (pp. 374–379)

1. The spinal cord attaches to the spinal nerves that innervate the neck, limbs, and trunk. It also acts as a reflex center and contains axon tracts running to and from the brain. It extends from the foramen magnum to the level of the first or second lumbar vertebra. The terminal end of the spinal cord is the conus medullaris.

2. Thirty-one pairs of spinal nerve roots issue from the spinal cord. The most inferior bundle of roots resembles a horse's tail (cauda equina). The spinal cord is enlarged in its cervical and lumbar regions, reflecting the innervation of the limbs.

White Matter of the Spinal Cord (p. 376)

3. The white matter of the cord is divided into dorsal, lateral, and ventral funiculi containing ascending and descending fibers.

Gray Matter of the Spinal Cord and Spinal Roots (pp. 376–378)

4. The H-shaped gray matter of the spinal cord has two ventral horns containing motor neurons and two dorsal horns containing interneurons. The dorsal horns are subdivided into somatic and visceral sensory regions; the ventral horns, into visceral and somatic motor regions.
5. The roots of the spinal nerves—dorsal sensory roots and ventral motor roots—are PNS structures that attach to the spinal cord.

Protection of the Spinal Cord (pp. 378–379)

6. Three connective-tissue membranes, the meninges, enclose and protect both the brain and the spinal cord: the tough outer dura mater, the arachnoid, and the inner vascularized pia mater.
7. Cerebrospinal fluid both floats and cushions the structures of the CNS. It fills the subarachnoid space and the central cavities of the brain and spinal cord.

The Brain (pp. 379–410)

8. The brain initiates voluntary and involuntary movements, interprets and integrates sensory stimuli, and is responsible for consciousness and cognitive function. It controls basic life-sustaining activities and it is also involved with the innervation of the head through the cranial nerves.

Embryonic Development of the Brain (p. 380)

9. The brain develops from the rostral part of the embryonic neural tube. By week 5, the early forebrain has become the telencephalon and diencephalon, the early midbrain has become the mesencephalon, and the early hindbrain has become the metencephalon and myelencephalon. As development continues after birth, the telencephalon becomes the cerebrum, the mesencephalon becomes the midbrain portion of the brain stem, the metencephalon becomes the pons portion of the brain stem and the cerebellum, and the myelencephalon becomes the medulla oblongata portion of the brain stem.
10. The cerebral hemispheres grow rapidly, enveloping the diencephalon and rostral brain stem. The expanding surfaces of the hemispheres fold into a complex pattern of sulci and gyri.

Basic Parts and Organization of the Brain (pp. 380–381)

11. A widely used classification scheme divides the brain into the cerebrum, diencephalon, brain stem (midbrain, pons, medulla), and cerebellum.
12. The brain stem and the diencephalon consist of white matter external to central gray matter, whereas the cerebrum and cerebellum have these two layers plus an additional, external cortex of gray matter.

Ventricles of the Brain (pp. 381–383)

13. The two lateral ventricles are in the cerebral hemispheres; the third ventricle is in the diencephalon; the cerebral aqueduct is in the midbrain; and the fourth ventricle is in the pons and medulla regions of the brain stem.

The Brain Stem (pp. 383–388)

14. The medulla oblongata contains the pyramids and their decussation, all formed by the pyramidal tracts. The olives contain relay nuclei to the cerebellum. Nuclei of cranial nerves VIII–XII lie near the fourth ventricle. Centers in the medullary reticular formation regulate respiration, heart rate, blood pressure, and other visceral functions.
15. In the pons, nuclei of cranial nerves V–VII lie near the fourth ventricle. The ventral region of the pons contains the pyramidal tracts plus the pontine nuclei that project to the cerebellum.

16. The midbrain is divided into a tectum and paired cerebral peduncles, with the latter containing the pyramidal motor tracts in the crus cerebri. In the tectum, the superior and inferior colliculi mediate visual and auditory reflexes. The red nucleus and substantia nigra participate in motor functions. The periaqueductal gray matter elicits the fear response. The midbrain also contains motor nuclei of cranial nerves III and IV, nerves that control eye muscles.

The Cerebellum (pp. 388–390)

17. The cerebellum smooths and coordinates body movements and helps maintain posture and equilibrium. Its main divisions—the paired cerebellar hemispheres and the vermis—are divided transversely into three lobes: anterior, posterior, and flocculonodular. The cerebellar surface is covered with folia (ridges) and fissures.
18. From superficial to deep, the main regions of the cerebellum are the cortex, the arbor vitae, and the deep cerebellar nuclei.
19. The cerebellar cortex receives sensory information on current body movements, then compares this information to how the body should be moving. In this way, it in effect carries out a dialogue with the cerebral cortex on how to coordinate precise voluntary movements.
20. The cerebellum connects to the brain stem by the superior, middle, and inferior cerebellar peduncles, thick fiber tracts that carry information to and from the cerebellum. All these fibers are ipsilateral.

The Diencephalon (pp. 390–393)

21. The diencephalon, which consists of the thalamus, hypothalamus, and epithalamus, encloses the third ventricle.
22. The thalamus, a paired egg-shaped group of brain nuclei, is the gateway to the cerebral cortex. It is a major relay station for sensory impulses ascending to the sensory cortex and for impulses from all brain regions that communicate with the cerebral cortex.
23. The hypothalamus, a series of brain nuclei, is the brain's most important visceral control center. It regulates sleep cycles, hunger, thirst, body temperature, secretion by the pituitary gland, the autonomic nervous system, and some emotions and behaviors.
24. The small epithalamus contains the pineal gland, which secretes a hormone called melatonin that is involved in the nighttime stage of the sleep-wake cycle.

The Cerebrum (pp. 393–406)

25. The two large cerebral hemispheres that make up the cerebrum have surface gyri, sulci, and fissures. The five lobes of each hemisphere are the frontal, parietal, occipital, and temporal lobes and the insula.
26. The cerebral cortex is the site of conscious sensory perception, voluntary initiation of movements, and higher thought functions. Structural regions of the six-layered cerebral cortex were identified by Brodmann and others.
27. Functionally, the cerebral cortex is divided into three areas. Sensory areas in the parietal, occipital, and temporal lobes are the location of the primary somatosensory cortex, primary visual cortex, primary auditory cortex, gustatory cortex, vestibular cortex, and olfactory cortex. Association areas contain both individual sensory association areas and multimodal association areas involved with integrating sensory input with past experience and planning motor response. Motor areas in the frontal lobe are the location of the premotor cortex, primary motor cortex, frontal eye field, and Broca's area for speech production.

28. Areas for higher-order visual processing occupy much of the temporal lobe (ventral stream for recognizing objects) and the posterior parietal lobe (dorsal stream for identifying spatial relationships). The language areas occupy a large part of the left cerebral cortex around the lateral sulcus. Auditory processing also follows two pathways: posterolateral for locating sound, and anterolateral for identifying sounds.
29. The cortex of each cerebral hemisphere receives sensory information from, and sends motor instructions to, the opposite (contralateral) side of the body. The body is mapped in an upside-down “homunculus” on the somatosensory and primary motor areas, an example of somatotopy.
30. The pyramidal tracts descend from the primary motor cortex and extend through the brain stem and the spinal cord, where they signal motor neurons to perform skilled voluntary movements.
31. In most people, the left cerebral hemisphere is specialized for language and math skills, and the right hemisphere is devoted more to visual-spatial and creative abilities.
32. In the cerebral white matter are found commissural fibers between hemispheres, association fibers between cortical areas within a hemisphere, and projection fibers to and from the brain stem and spinal cord.
33. The basal ganglia, one component of the deep gray matter of the cerebrum, are embedded deep in the cerebral white matter. The structures of the basal ganglia include the caudate nucleus, the putamen, and the globus pallidus. Functionally, the basal ganglia work with the cerebral motor cortex to control complex movements, among other functions.
34. The basal forebrain nuclei, located anterior and dorsal to the hypothalamus, are part of the basal forebrain cholinergic system whose functions relate to arousal, learning, memory, and motor control.

Functional Brain Systems (pp. 406–407)

35. The limbic system consists of many cerebral and diencephalic structures on the medial aspect of each cerebral hemisphere. It is the “emotional-visceral” part of the brain, and it also forms and retrieves memories. The hippocampus and amygdala consolidate memories of facts and emotions, respectively.
36. The reticular formation includes diffuse brain nuclei that span the length of the brain stem. The reticular activating system of the reticular formation maintains the conscious state of the cerebral cortex, and the reticulospinal tracts signal many nonskilled body movements.

Protection of the Brain (pp. 407–410)

37. The brain is protected by skull bones, meninges, cerebrospinal fluid, and the blood-brain barrier.
38. The three meninges form continuous coverings around the spinal cord and brain. Internal projections of the dura mater surrounding the brain form partitions (falx cerebri, falx cerebelli, tentorium cerebelli) that secure the brain in the skull.

39. Cerebrospinal fluid is derived from blood plasma at the choroid plexuses in the roof of the ventricles. It circulates through the ventricles and into the subarachnoid space, and returns to the blood through arachnoid villi at the superior sagittal sinus.
40. The blood-brain barrier derives from the relative impermeability of brain capillaries (complete tight junctions between endothelial cells). The barrier lets water, oxygen, nutrients, and fat-soluble molecules enter the neural tissue but prevents entry of most harmful substances.

Sensory and Motor Pathways in the Central Nervous System (pp. 410–417)

Ascending Pathways (pp. 412–415)

41. The ascending spinal tracts in the funiculi of the spinal cord belong to sensory pathways that run from the body periphery to the brain. These include the spinocerebellar pathway (for proprioception) to the cerebellum and two pathways to the somatosensory cortex: the dorsal column pathway (for discriminative touch and proprioception) and the spinothalamic pathway (for pain, temperature, and nondiscriminative touch).

Descending Pathways (pp. 415–417)

42. The descending tracts in the funiculi of the spinal cord belong to motor pathways that connect the brain to the body muscles. These include the pyramidal (corticospinal) tracts that control skilled movements and other fiber tracts that control subconscious and coarse movements.

PAL Human Cadaver/Nervous System/Central Nervous System

Disorders of the Central Nervous System (pp. 417–419)

Spinal Cord Damage (p. 418)

43. Transection, tearing, or crushing of the spinal cord permanently eliminates voluntary movements and sensation inferior to the damage site.

Brain Dysfunction (pp. 418–419)

44. Blows to the head may cause concussions. These injuries can be aggravated by intracranial bleeding and swelling of the brain.
45. Cerebrovascular accidents (strokes) result either when the blood vessels to the brain tissue are blocked or when blood flow to the brain is interrupted, causing the tissue to die.
46. Alzheimer’s disease is a degenerative brain disease affecting the cerebral cortex and hippocampus. Mental functions diminish progressively.

The Central Nervous System Throughout Life (pp. 420–421)

47. Birth defects that involve the brain include congenital hydrocephalus, neural tube defects (anencephaly, spina bifida), and cerebral palsy. Spina bifida cystica is associated with meningocele and/or myelomeningocele cysts.
48. The brain forms many neuronal connections during childhood, all based on early life experiences. Growth of the brain stops in young adulthood, and cognitive functions decline slowly with age.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Choose the correct brain structure from the key for each of the following descriptions. Some letters are used more than once.

Key:

- | | |
|-------------------------------------|--------------|
| (a) cerebellum | (f) medulla |
| (b) superior and inferior colliculi | (g) midbrain |
| (c) corpus striatum | (h) pons |
| (d) corpus callosum | (i) thalamus |
| (e) hypothalamus | |

- _____ (1) basal ganglia involved in motor activities; related to Huntington's disease
 - _____ (2) region where there is a crossover of fibers of pyramidal tracts
 - _____ (3) control of temperature, autonomic nervous system, hunger, and water balance
 - _____ (4) houses the substantia nigra and red nucleus
 - _____ (5) involved in visual and auditory reflexes; found in midbrain
 - _____ (6) part of diencephalon with vital centers controlling heart rate, some aspects of emotion, and blood pressure
 - _____ (7) all inputs to cerebral cortex must first synapse in one of its nuclei
 - _____ (8) brain area that has folia and coordinates movements
 - _____ (9) brain region that contains the cerebral aqueduct
 - _____ (10) associated with fourth ventricle and contains nuclei of cranial nerves V–VII
 - _____ (11) thick tract between the two cerebral hemispheres
2. A patient suffered a cerebral hemorrhage that damaged the post-central gyrus in her right cerebral hemisphere. As a result, she (a) cannot voluntarily move her left arm or leg, (b) feels no sensation on the left side of her body, (c) feels no sensation on the right side of her body, (d) can no longer play the violin.
 3. Destruction of the ventral horn cells of the spinal cord results in loss of (a) intelligence, (b) all sensation, (c) pain, (d) motor control.
 4. For each of the following brain structures, write G (for gray matter) or W (for white matter) as appropriate.
 - _____ (1) cortex of cerebellum
 - _____ (2) pyramids
 - _____ (3) internal capsule and corona radiata
 - _____ (4) red nucleus
 - _____ (5) medial lemniscus
 - _____ (6) cranial nerve nuclei
 - _____ (7) cerebellar peduncle
 5. Which of the following areas is most likely to store visual memories? (a) visual association area, (b) Wernicke's area, (c) premotor cortex, (d) primary somatosensory cortex.

Short Answer Essay Questions

6. Make a diagram showing the five secondary brain vesicles of an embryo, and then list the basic adult brain regions derived from each.
7. (a) Make a rough sketch of a lateral view of the left cerebral hemisphere. (b) You may be thinking, "But I just can't draw!" So, name the hemisphere involved in most people's ability to draw. (c) On your drawing, locate the following areas, and identify their major functions: primary motor cortex, premotor cortex, somatosensory association area, primary visual area, prefrontal cortex, Broca's area.
8. (a) Name the brain nuclei that make up the basal ganglia. (b) What is the basic function of the basal ganglia? (c) Which nucleus arches over the thalamus?
9. Describe the role of the cerebellum in maintaining smooth, coordinated skeletal muscle activity.
10. (a) Where is the limbic system located? (b) What structures make up this system? (c) How is the limbic system important in behavior?
11. (a) Describe the location of the reticular formation in the brain. (b) What does RAS mean, and what is its function?
12. (a) List four ways in which the CNS is protected. (b) How is cerebrospinal fluid formed and drained? Describe its pathway within and around the brain.
13. (a) What are the superior and inferior boundaries of the spinal cord in the vertebral canal? (b) A correctly executed lumbar spinal tap could poke the cauda equina or filum terminale, but not the conus medullaris. Explain.
14. (a) Which of the ascending tracts in the spinal cord carry sensory impulses concerned with discriminative touch and pressure? (b) Which are concerned with proprioception only?
15. (a) In the spinothalamic pathway, where are the cell bodies of the first-order neurons located? Of the third-order neurons? (b) Trace the descending pathway that is concerned with skilled voluntary movements.
16. List a few changes in brain structure that occur with aging.
17. Define somatotopy, and give one example of it in the brain and one example in the spinal cord.
18. A brain surgeon removed a piece of a woman's skull and cut through all the meninges to reach the brain itself. Name all the layers that were cut, from skin to brain.
19. What are some of the functional differences between the right and the left cerebral hemispheres?
20. Sketch the spinal cord in cross section, and label the following structures: (a) lateral funiculus of white matter, (b) ventral root, (c) ventral horn of gray matter, (d) central canal, (e) dorsal root ganglion, (f) dorsal column tracts: fasciculus gracilis and fasciculus cuneatus, (g) ventral corticospinal tract, (h) lateral corticospinal tract.
21. Describe the location and function of the periaqueductal gray matter.
22. Describe the location and function of the ventral stream of visual-processing areas in the cerebral cortex. Then explain why the dorsal and ventral visual streams are called the "where" and "what" streams, respectively.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Kimberly learned that the basic design of the CNS is gray matter on the inside and white matter on the outside. When her friend L'Shawn said that there is gray matter on the outside of the cerebrum of the brain, Kim became confused. Clear up her confusion.
2. When Ralph had brain surgery to remove a small intracranial hematoma (blood mass), the operation was done under local anesthesia because he was allergic to general anesthetic agents. The surgeon removed a small part of the skull, and Ralph remained conscious. The operation went well, and when Ralph asked the surgeon to stimulate his (unharmful) postcentral gyrus mildly with an electrode, the surgeon did so. Indicate which of the following happened, and explain why: (a) Ralph was seized with uncontrollable rage. (b) He saw things that were not there. (c) He asked to see what was touching his hand, but nothing was. (d) He started to kick. (e) He heard his mother's voice from 30 years ago.
3. When their second child was born, Kiko and Taka were told their baby had spina bifida and would be kept in intensive care for a week. After that time, a "shunt" would be put in. Also, immediately after the birth, an operation was performed on the infant's lower back. The parents were told that this operation went well but that their son would always be a "little weak in the ankles." Explain the statements in quotation marks in more informative and precise language.
4. Cesar, a brilliant computer analyst, was hit on the forehead by a falling rock while mountain climbing. It was soon obvious to his coworkers that his behavior had changed dramatically. He had been a smart dresser, but now he was unkempt, and he started revealing the most secret office gossip to everyone. When he was discovered barefoot, washing his socks in the employee lounge, his supervisor ordered Cesar to report to the company doctor. What region of Cesar's brain was affected by the cranial blow?
5. One war veteran was quadriplegic, and another was paraplegic. Explain the relative locations of their injuries.
6. Every time Spike went to a boxing match, he screamed for a knockout. Then his friend Rudy explained what happens when someone gets knocked out. What is the explanation?
7. A spinal cord injury at C₂ results not only in paralysis but also in a lifetime on a respirator. Why does an injury this high affect ability to breathe?
8. What parts of the brain are still developing during adolescence, and how does this lag contribute to the types of behavior typical of this age: mood swings, risky behavior, and poor judgment?
9. Strokes, tumors, or wounds can destroy limited areas of the brain. What are the effects of localized lesions to the primary motor cortex?



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14

The Peripheral Nervous System

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The Peripheral Nervous System Throughout Life 458

The human brain, for all its sophistication, would be useless without its sensory and motor connections to the outside world. Our very sanity depends on a continual flow of sensory information from the environment. When blindfolded volunteers were suspended in a tank of warm water (a sensory-deprivation tank), they began to hallucinate: One saw pink and purple elephants, another heard a singing chorus, and others had taste hallucinations. Our sense of well-being also depends on our ability to carry out motor instructions sent from the CNS. Many victims of spinal cord injuries experience despair at being unable to move or take care of their own needs. The **peripheral nervous system (PNS)**—the

Myelinated and non-myelinated axons from the human peripheral nervous system (colored TEM).

Segmentation By \ Belal Shams AIDin

THE PERIPHERAL NERVOUS SYSTEM THROUGHOUT LIFE

- Relate the development of the PNS to the basic segmental pattern of the outer tube of the human body.

The spinal nerves start to form late in the fourth week of development. Motor axons grow outward from the early spinal cord, whereas sensory peripheral axons grow out from the neural crest of the dorsal root ganglia (see Figure 12.16, p. 368). The bundles of these motor and sensory axons exit between successive developing vertebrae, where they converge to form the early spinal nerves. Each of the 31 spinal nerves sends motor fibers into a single myotome, and sensory fibers to the overlying band of skin, which accounts for the segmented pattern of dermatomes. Cranial nerves grow to innervate the head in a roughly comparable manner. Some of their sensory neurons—those for some of the special senses—develop from plate-shaped thickenings of the head ectoderm called **ectodermal placodes** (plak'odz; "platelike"); others develop from the neural crest.

During week 5 of development, nerves reach the organs they innervate. Shortly thereafter, some of the embryonic

muscles migrate to new locations, and some skin dermatomes become displaced as they are pulled along the elongating limbs. Even though they may migrate for considerable distances, these muscles and skin areas always retain their original nerve supply.

Aging of the nervous system is discussed in Chapters 12 and 13. In the PNS, sensory receptors atrophy to some degree with age, and tone in the muscles of the face and neck decreases. Reflexes slow a bit with age, but this change seems to reflect a slowing of central processing more than changes in peripheral nerve fibers.

check your understanding

19. Use the word roots at the back of the text to define these terms: (a) neuralgia, (b) paresthesia, (c) neuropathy.
20. Does postpolio syndrome result from a dormant poliovirus becoming active again?

For answers, see Appendix B.

RELATED CLINICAL TERMS

NERVE INJURIES The following terms describe various injuries, listed here in order of increasing severity. (1) *Neurapraxia* is a temporary and incomplete loss of nerve function, resulting from pressure and the ensuing ischemia; only the myelin is seriously harmed, and it regenerates so that function returns in a few weeks. (2) *Axonotmesis* is an injury that causes breaks in the axons, but the surrounding epineurium remains intact; axonal regrowth proceeds at the rate of about a centimeter a week. (3) In *neurotmesis*, the whole nerve is severed. Surgical reconnection is necessary for regeneration to occur.

NEURALGIA (nu-ral'je-ah) (*algia* = pain) Sharp, spasmlike pain along the course of one or more nerves, usually caused by inflammation or injury to the nerves.

NEURITIS Inflammation of a nerve. There are many different forms of neuritis with different effects, including increased or decreased nerve sensitivity, paralysis of the structure served, and pain.

SCAPULAR WINGING Condition in which the medial border of the scapula projects posteriorly, due to the paralysis of the serratus anterior muscle. The ultimate cause is damage to the long thoracic nerve supplying the serratus anterior.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 14.

PAL = Practice Anatomy Lab™

Organization of the Peripheral Nervous System (p. 427)

1. The PNS consists of sensory receptors, motor endings that innervate effector organs, nerves, and ganglia. Most nerves contain both sensory and motor fibers (mixed nerves), but some are purely sensory or purely motor.

Peripheral Sensory Receptors (pp. 427–431)

2. Sensory receptors monitor stimuli (environmental changes) from both inside and outside the body. The widespread receptors for the general senses tend to be free nerve endings of sensory neurons, whereas the localized receptors for the special senses tend to be distinct receptor cells.

Classification by Location (p. 428)

3. Receptors are classified by location as exteroceptors for external stimuli, interoceptors for internal stimuli in the viscera, and proprioceptors for measuring stretch in muscles and the skeleton.

Classification by Stimulus Detected (p. 428)

4. Receptors are classified by stimuli detected as mechanoreceptors, thermoreceptors, chemoreceptors, photoreceptors, and nociceptors.

Classification by Structure (pp. 428–431)

5. Nerve endings of sensory neurons monitor general sensory information. Structurally, they are either (1) free nerve endings or (2) encapsulated nerve endings. The free endings are mainly receptors for pain and temperature, although two are for light touch: epithelial tactile complexes (Merkel discs) and hair follicle receptors. The encapsulated endings are mechanoreceptors: They include

tactile (Meissner's) corpuscles (discriminative touch), lamellar (Pacinian) corpuscles and bulbous corpuscles (Ruffini endings, deep pressure), and most proprioceptors.

6. The proprioceptors include muscle spindles, tendon organs (Golgi tendon organs), and joint kinesthetic receptors. Muscle spindles are small bags of muscle fibers (intrafusal fibers) innervated by sensory nerve endings within the skeletal muscles of the body. They monitor muscle length by measuring muscle stretch.
7. Tendon organs (Golgi tendon organs) are encapsulated nerve endings embedded in muscle tendons. They monitor the tension generated in tendons during muscle contraction. Joint kinesthetic receptors occur in joint capsules. Some joint receptors measure tension placed on the joint (lamellar corpuscles and bulbous corpuscles). Free nerve endings in joints are receptors for pain.

Cranial Nerves (pp. 431–439)

8. Twelve pairs of cranial nerves originate from the brain and issue through the skull to innervate the head and neck. Only the vagus nerves extend into the thoracic and abdominal cavities.
9. The following are the cranial nerves:
 - I. The olfactory nerves: purely sensory; concerned with smell; attach to the olfactory bulb of the cerebrum.
 - II. The optic nerves: purely sensory; transmit visual impulses from the retina to the thalamus.
 - III. The oculomotor nerves: primarily motor; emerge from the midbrain and serve four extrinsic muscles that move the eye and some smooth muscle within the eye; also carry proprioceptive impulses from the skeletal muscles served.
 - IV. The trochlear nerves: primarily motor; emerge from the dorsal midbrain and carry motor and proprioceptive impulses to and from superior oblique muscles of the eyes.
 - V. The trigeminal nerves: contain both sensory and motor fibers; emerge from the pons; the main general sensory nerves of the face, nasal cavity, and mouth; three divisions: ophthalmic, maxillary, and mandibular; the mandibular branch contains motor fibers that innervate the chewing muscles.
 - VI. The abducens nerves: primarily motor; emerge from the pons and supply motor and proprioceptive innervation to the lateral rectus muscles of the eyes.
 - VII. The facial nerves: contain both sensory and motor fibers; emerge from the pons; motor nerves to muscles of facial expression, sublingual and submandibular salivary glands, and the lacrimal glands; also carry sensory impulses from the taste buds of anterior two-thirds of the tongue.
 - VIII. The vestibulocochlear nerves: primarily sensory; enter brain at the pons-medulla border; transmit impulses from the hearing and equilibrium receptors of the inner ears.
 - IX. The glossopharyngeal nerves: contain both sensory and motor fibers; issue from the medulla; transmit sensory impulses from the posterior tongue (including taste) and the pharynx; innervate the stylopharyngeus muscle and parotid gland.
 - X. The vagus nerves: contain both sensory and motor fibers; arise from the medulla; most of its motor fibers are autonomic; carry motor fibers to, and sensory fibers from, the pharynx, larynx, and visceral organs of the thorax and abdomen.
 - XI. The accessory nerves: primarily motor; arise from the cervical spinal cord; supply the trapezius and sternocleidomastoid.
 - XII. The hypoglossal nerves: primarily motor; issue from the medulla; supply motor innervation to the tongue muscles.
10. The cranial nerves can be grouped according to function. Some are *sensory*, containing special somatic sensory fibers (I, II, VIII); some are primarily *motor*, containing somatic motor fibers (III, IV, VI, XI, and XII); and some are *mixed*, containing both sensory and motor fibers (V, VII, IX, X).

Spinal Nerves (pp. 439–456)

11. The 31 pairs of spinal nerves are numbered according to the region of the vertebral column from which they issue: cervical, thoracic, lumbar, sacral, and coccygeal. There are 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal spinal nerves.
12. Each spinal nerve forms from the union of a dorsal sensory root and a ventral motor root in an intervertebral foramen. On each dorsal root is a dorsal root ganglion containing the cell bodies of sensory neurons. The branches of each spinal nerve are the dorsal and ventral rami (somatic branches) and rami communicantes (visceral branches).
13. Dorsal rami serve the muscles and skin of the posterior trunk, whereas ventral rami serve the muscles and skin of the lateral and anterior trunk. Ventral rami also serve the limbs.
14. The back, from neck to sacrum, is innervated by the dorsal rami in a neatly segmented pattern.
15. The anterior and lateral wall of the thorax (and abdomen) are innervated by thoracic ventral rami—the segmented intercostal and subcostal nerves. Thoracic ventral rami do not form nerve plexuses.
16. The major nerve plexuses are networks of successive ventral rami that exchange fibers. They primarily innervate the limbs.
17. The cervical plexus (C₁–C₄) innervates the muscles and skin of the neck and shoulder. Its phrenic nerve (C₃–C₅) serves the diaphragm.
18. The brachial plexus serves the upper limb, including the muscles of the shoulder girdle. It arises primarily from C₅–T₁. From proximal to distal, the brachial plexus consists of “roots” (ventral rami), trunks, divisions, and cords.
19. The main nerves arising from the brachial plexus are the musculocutaneous (to flexors on the arm), median (to anterior forearm muscles and the lateral palm), ulnar (to anteromedial muscles of the forearm and the medial hand), axillary (to the deltoid and teres minor muscles), and radial (to the posterior part of the upper limb).
20. The lumbar plexus (L₁–L₄) innervates the anterior and medial muscles of the thigh, through the femoral and obturator nerves, respectively. The femoral nerve also innervates the skin on the anterior thigh and medial leg.
21. The sacral plexus (L₄–S₄) supplies the muscles and skin of the posterior thigh and almost all of the leg. Its main branch is the large sciatic nerve, which consists of the tibial nerve (to most of the hamstrings and all muscles of the calf and sole) and the common fibular nerve (to muscles of the anterior and lateral leg and the overlying skin). Other branches of the sacral plexus supply the posterior and lateral muscles of the pelvic girdle (such as the gluteal muscles) and the perineum (pudendal nerve).
22. A dermatome is a segment of skin innervated by the sensory fibers of a single spinal nerve. Adjacent dermatomes overlap to some degree, more so on the trunk than on the limbs. Loss of sensation in

specific dermatomes reveals sites of damage to spinal nerves or the spinal cord.

23. The sensory nerves to a joint are branches of the nerves innervating the muscles that cross that joint (Hilton's law).

PAL Human Cadaver/Nervous System/Peripheral Nervous System

Disorders of The Peripheral Nervous System (pp. 456–458)

24. Shingles and migraine headaches are painful sensory disorders of dermatomes and the brain arteries, respectively. Peripheral neu-

ropathy refers to any pathology of the peripheral nerves that disrupts nerve function.

The Peripheral Nervous System Throughout Life (p. 458)

25. During embryonic development, each spinal nerve grows out between newly formed vertebrae to provide the motor innervation of an adjacent myotome (future trunk muscle) and the sensory innervation of the adjacent skin region (dermatome).

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Proprioceptors include all of the following except (a) muscle spindles, (b) tendon organs, (c) epithelial tactile complexes, (d) lamellar corpuscles in joint capsules.
- The large, onion-shaped pressure receptors in deep connective tissues are (a) epithelial tactile complexes, (b) lamellar corpuscles, (c) free nerve endings, (d) bulbous corpuscles.
- Choose the correct receptor type from column B for each description given in column A.

Column A

- ____ (1) pain, itch, and temperature receptors
- ____ (2) contain intrafusal fibers and secondary sensory endings
- ____ (3) discriminative touch receptors in hairless skin (fingertips)
- ____ (4) contain nerve endings wrapped around thick collagen bundles in a tendon
- ____ (5) rapidly adapting deep-pressure receptors
- ____ (6) slowly adapting deep-pressure receptors

Column B

- (a) bulbous corpuscles
- (b) tendon organs
- (c) muscle spindles
- (d) free nerve endings
- (e) lamellar corpuscles
- (f) tactile corpuscles

4. Choose the correct cranial nerves from the key for each description below.

Key:

- | | |
|----------------------|-----------------------|
| (a) abducens | (g) olfactory |
| (b) accessory | (h) optic |
| (c) facial | (i) trigeminal |
| (d) glossopharyngeal | (j) vestibulocochlear |
| (e) hypoglossal | (k) vagus |
| (f) oculomotor | (l) trochlear |
- ____ (1) innervates four extrinsic eye muscles
 - ____ (2) is the major sensory nerve of the face
 - ____ (3) innervates the sternocleidomastoid and trapezius
 - ____ (4) are primarily or exclusively sensory (three nerves)
 - ____ (5) innervates the tongue muscles
 - ____ (6) allows chewing of food

- ____ (7) is anesthetized during dental work
- ____ (8) helps to regulate heart activity
- ____ (9) sensory innervation for hearing and equilibrium
- ____ (10) contain parasympathetic motor fibers (four nerves)
- ____ (11) innervates muscles of facial expression

5. For each of the following muscles or body regions, identify the plexus and the peripheral nerve (or branch of one) involved. Use one choice from Key A followed by one choice from Key B.

Key A: Plexuses

- (a) brachial
- (b) cervical
- (c) lumbar
- (d) sacral

Key B: Nerves

- (1) common fibular
- (2) femoral
- (3) median
- (4) musculocutaneous
- (5) obturator
- (6) phrenic
- (7) radial
- (8) tibial
- (9) ulnar

Structure Innervated

- ____, ____ (1) the diaphragm
 - ____, ____ (2) muscles of the posterior compartments of thigh and leg
 - ____, ____ (3) anterior compartment thigh muscles
 - ____, ____ (4) medial compartment thigh muscles
 - ____, ____ (5) anterior arm muscles that flex the forearm
 - ____, ____ (6) muscles that flex the wrist and fingers (two nerves)
 - ____, ____ (7) muscles that extend the wrist and fingers
 - ____, ____ (8) skin and extensor muscles of the posterior arm
 - ____, ____ (9) fibular muscles, tibialis anterior, and toe extensors
- Which one of the following contains only motor fibers? (a) dorsal root, (b) dorsal ramus, (c) ventral root, (d) ventral ramus.
 - The trigeminal nerve contains which class(es) of nerve fibers? (a) somatic sensory only, (b) somatic motor and proprioceptor, (c) general sensory and somatic motor.
 - Whereas *bronchial* refers to the airways in the lungs, *brachial* refers to the (a) back, (b) pharynx, (c) arm, (d) thigh.
 - Which cranial nerves contain somatic motor axons to pharyngeal arch muscles (see p. 265)? (a) I, II, VII; (b) V, VII, IX, X, XI; (c) III, IV, VI, XI, XII.
 - Which of the following components occur in all of the mixed cranial nerves V, VII, IX, and X? Choose as many as apply: (a) general

somatic sensory; (b) special somatic sensory; (c) general visceral sensory; (d) special visceral sensory (taste), (e) somatic motor to pharyngeal arch muscles.

Short Answer Essay Questions

11. In the sensory receptors called “encapsulated nerve endings,” what is the “capsule” made of?
12. (a) Describe the roots to and the composition of a spinal nerve. (b) Are dorsal and ventral roots in the CNS or the PNS? (c) Name the branches of a spinal nerve (other than the rami communicantes), and identify what basic region of the body each branch supplies.
13. (a) Define nerve plexus. (b) List the spinal nerves of origin of the four major nerve plexuses, and name the general body regions served by each plexus.
14. In the brachial plexus, what specific rami make up each of the three trunks?
15. Adrian and Abdul, two anatomy students, were arguing about the facial nerve. Adrian said that it innervates all of the skin of the face, and that it is called the facial nerve for this reason. Abdul claimed the facial nerve does not innervate facial skin at all. Who was correct?
16. Choose the correct answer, and explain why it is correct. Through which pair of intervertebral foramina do spinal nerves L₅ leave the vertebral canal? (a) holes in the sacrum, (b) just superior to vertebra L₅, (c) just superior to S₁, (d) just inferior to S₄.
17. There are 40 roots in the cauda equina. To what spinal nerves do they belong? (See p. 374.)

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. As Harry was falling off a ladder, he reached out and grabbed a tree branch with his hand. His overstretched upper limb became weak and numb. What major nervous structure had he injured?
2. Frita, in her early 70s, had problems chewing. When she was asked to stick out her tongue, it deviated to the right, and its right half was quite wasted. What nerve was injured?
3. Ted is a war veteran who was hit in the back with small pieces of shrapnel. His skin is numb in the center of his buttocks and along the entire posterior side of a lower limb, but there is no motor problem. Indicate which of the following choices is the most likely site of his nerve injury, and explain your choice: (a) a few dorsal roots of the cauda equina, (b) spinal cord transection at C₆, (c) spinal cord transection at L₅, (d) femoral nerve transected in the lumbar region.
4. A quarterback suffered torn menisci in his right knee joint when he was tackled from the side. The same collision crushed his common fibular nerve against the neck of his right fibula. What locomotor problems can he expect to experience from this nerve injury?
5. In a patient who developed carpal tunnel syndrome, the nerve injury began as a neurapraxia and then became an axonotmesis. (1) Recall what nerve is affected in carpal tunnel syndrome (see Chapter 8, p. 190). (2) Explain the terms *neurapraxia* and *axonotmesis*. (3) Describe the sensory and motor losses experienced. (4) Estimate how long full recovery from this nerve injury will take. (See Related Clinical Terms.)
6. Using Hilton’s law, (1) deduce which four nerves send branches that innervate the capsule of the elbow joint and (2) identify the nerves that supply the hip joint.
7. After suffering from a broken humerus, a patient was unable to extend her wrist and complained of paresthesia on the back of her hand. What nerve must have been injured in the humeral break?
8. Name all of the nerves that innervate the tongue.



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15 The Autonomic Nervous System and Visceral Sensory Neurons

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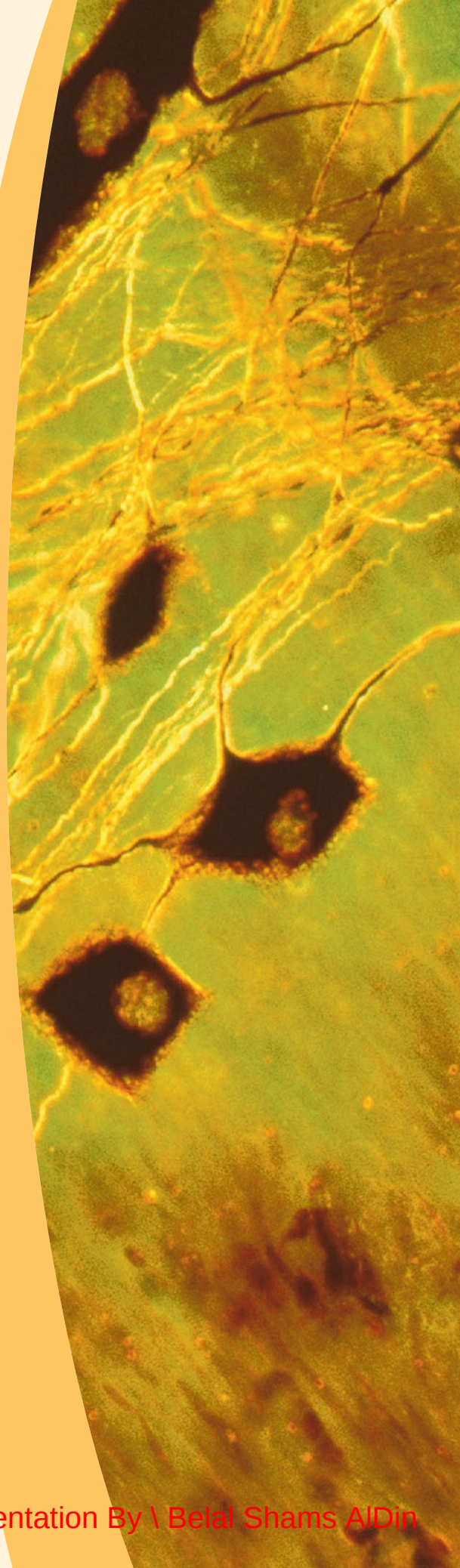
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Neurons of the myenteric plexus in a section of the small intestine (light micrograph 1200×).

RELATED CLINICAL TERMS

ATONIC BLADDER (a-tahn'ik; "without tone") A condition in which the bladder becomes flaccid and overfills, allowing urine to dribble out. Atonic bladder results from the temporary loss of the micturition reflex following injury to the spinal cord.

VAGOTOMY (va-got'o-me) Cutting or severing of a vagus nerve, often to decrease the secretion of stomach acid and other caustic digestive juices that aggravate ulcers.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 15.

PAL = Practice Anatomy Lab™

1. The ANS is the system of motor neurons that innervates smooth muscle, cardiac muscle, and glands. It is the general visceral motor division of the PNS. The ANS largely operates below the level of consciousness.

Overview of the Autonomic Nervous System (pp. 463–466)

Comparison of the Autonomic and Somatic Motor Systems (pp. 463–464)

2. In the somatic motor division of the nervous system, a single motor neuron forms the pathway from the CNS to the effectors. Autonomic motor pathways, by contrast, consist of chains of two neurons: the preganglionic neuron, whose cell body is in the CNS, and the postganglionic neuron, whose cell body is in an autonomic ganglion. The axonal processes of these neurons are also called fibers.

Divisions of the Autonomic Nervous System (pp. 464–466)

3. The ANS has parasympathetic and sympathetic divisions. Both innervate many of the same organs but produce opposite effects. The sympathetic division prepares the body for "fight or flight," whereas the parasympathetic division is active during "rest and digest." Details of the effects of both divisions are listed in Table 15.2 (p. 474).
4. The parasympathetic division exits the CNS on cranial and sacral nerves and has comparatively long preganglionic axons. The sympathetic division exits on thoracic and lumbar nerves and has comparatively long postganglionic axons.
5. The two divisions differ in the neurotransmitters they release at the effector organ. Acetylcholine is released by parasympathetic postganglionic fibers, whereas norepinephrine is released by most sympathetic postganglionic fibers.

The Parasympathetic Division (pp. 466–469)

Cranial Outflow (pp. 466–469)

6. Cranial parasympathetic fibers arise in the brain stem nuclei of cranial nerves III, VII, IX, and X and synapse in ganglia in the head, thorax, and abdomen. Fibers in cranial nerve (CN) III serve smooth musculature in the eye via a synapse in the ciliary ganglion. Fibers in CN VII serve the submandibular, sublingual, lacrimal, and nasal glands and synapse in the submandibular and pterygopalatine ganglia. Fibers in CN IX serve the parotid gland via a synapse in the otic ganglion.

7. Parasympathetic fibers in the vagus nerve (CN X) innervate organs in the thorax and most of the abdomen, including the heart, lungs, esophagus, stomach, liver, and most of the intestines. The fibers in the vagus are preganglionic. Almost all postganglionic neurons are located in intramural ganglia within the organ walls.

Sacral Outflow (p. 469)

8. Sacral parasympathetic pathways innervate the pelvic viscera. The preganglionic fibers exit from the visceral motor region of the gray matter of the spinal cord (S₂–S₄) and form the pelvic splanchnic nerves. Most of these fibers synapse in intramural ganglia in the pelvic organs.

The Sympathetic Division (pp. 469–474)

Basic Organization (pp. 469–471)

9. The preganglionic sympathetic cell bodies are in the lateral horn of the spinal gray matter from the level of T₁ to L₂.
10. The sympathetic division supplies some peripheral structures that the parasympathetic division does not: arrector pili, sweat glands, and the smooth muscle of blood vessels.
11. Sympathetic ganglia include 22–24 pairs of sympathetic trunk ganglia (also called chain ganglia and paravertebral ganglia), which are linked together to form sympathetic trunks on both sides of the vertebral column, and unpaired collateral ganglia (prevertebral ganglia), most of which lie on the aorta in the abdomen.

Sympathetic Pathways (pp. 471–474)

12. Every preganglionic sympathetic fiber leaves the lateral gray horn of the thoracolumbar spinal cord through a ventral root and spinal nerve. From there, it runs in a white ramus communicans to a sympathetic trunk ganglion or collateral ganglion, where it synapses with the postganglionic neuron that extends to the visceral effector. Many preganglionic axons ascend or descend in the sympathetic trunk to synapse in a ganglion at another body level.
13. In the sympathetic pathway to the body periphery (to innervate arrector pili, sweat glands, and peripheral blood vessels), the preganglionic fibers synapse in the sympathetic trunk ganglia, and the postganglionic fibers run in gray rami communicantes to the dorsal and ventral rami of the spinal nerves for peripheral distribution.
14. In the sympathetic pathway to the *head*, the preganglionic fibers ascend in the sympathetic trunk and synapse in the superior cervical ganglion. From there, most postganglionic fibers associate with a large artery that distributes them to the glands and smooth musculature of the head.
15. In the sympathetic pathway to *thoracic organs*, most preganglionic fibers synapse in the nearest sympathetic trunk ganglion, and the postganglionic fibers run directly to the organs (lungs, esophagus). Many postganglionic fibers to the heart, however, descend from the cervical ganglia in the neck.

16. In the sympathetic pathway to *abdominal organs*, the preganglionic fibers run in splanchnic nerves to synapse in collateral ganglia on the aorta. From these ganglia, the postganglionic fibers follow large arteries to the abdominal viscera (stomach, liver, kidney, and most of the large intestine).
17. In the sympathetic pathway to *pelvic organs*, the preganglionic fibers synapse in sympathetic trunk ganglia or in collateral ganglia on the aorta, sacrum, and pelvic floor. Postganglionic fibers travel through the most inferior autonomic plexuses to the pelvic organs.

The Role of the Adrenal Medulla in the Sympathetic Division (p. 474)

18. The adrenal glands, one superior to each kidney, contain a medulla of modified postganglionic sympathetic neurons that secrete the hormones epinephrine (adrenaline) and norepinephrine into the blood. The result is the “surge of adrenaline” felt during excitement.
19. The cells of the adrenal medulla are innervated by preganglionic sympathetic neurons, which signal them to secrete the hormones.

PAL Human Cadaver/Nervous System/Autonomic Nervous System

Visceral Sensory Neurons (p. 475)

20. General visceral sensory neurons monitor temperature, pain, irritation, chemical changes, and stretch in the visceral organs.
21. Visceral sensory fibers run within the autonomic nerves, especially within the vagus and the sympathetic nerves. Most pain fibers from the visceral organs of the body follow the sympathetic pathway to the CNS and are carried in the spinothalamic tract to the thalamus and then to the visceral sensory cortex.

22. Visceral pain is induced by stretching, infection, and cramping of internal organs but seldom by cutting or scraping these organs. Visceral pain is referred to somatic regions of the body that receive innervation from the same spinal cord segments.

Visceral Reflexes (pp. 475–476)

23. Many visceral reflexes are spinal reflexes, such as the defecation reflex. Others, such as the baroreceptor reflex, involve integration centers in the brain stem. Some visceral reflexes, however, involve only peripheral neurons.

Central Control of the Autonomic Nervous System (pp. 476–477)

24. Visceral motor functions are influenced by the medulla oblongata, the periaqueductal gray matter, spinal visceral reflexes, the hypothalamus, the amygdala, and the cerebral cortex. Some people can voluntarily regulate some autonomic activities by gaining extraordinary control over their emotions.

Disorders of the Autonomic Nervous System (pp. 477–478)

25. Most autonomic disorders reflect problems with the control of smooth muscle. Raynaud’s disease and hypertension result from abnormalities in vascular control. The mass reflex reaction affects some individuals with spinal cord injuries.

The Autonomic Nervous System Throughout Life (p. 478)

26. Preganglionic neurons develop from the neural tube. Postganglionic neurons and visceral sensory neurons develop from the neural crest.
27. The efficiency of the ANS declines in old age: Gastrointestinal motility and production of tears decrease, and the vasomotor response to standing slows.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Which of the following does *not* characterize the ANS? (a) two-neuron motor chains, (b) preganglionic cell bodies in the CNS, (c) presence of postganglionic cell bodies in ganglia, (d) innervation of skeletal muscle.

2. For each of the following terms or phrases, write either S (for sympathetic) or P (for parasympathetic) division of the autonomic nervous system.

- _____ (1) short preganglionic fibers, long postganglionic fibers
- _____ (2) intramural ganglia
- _____ (3) craniosacral outflow
- _____ (4) adrenergic fibers
- _____ (5) cervical ganglia of the sympathetic trunk
- _____ (6) otic and ciliary ganglia
- _____ (7) more widespread response
- _____ (8) increases heart rate, respiratory rate, and blood pressure
- _____ (9) increases motility of stomach and secretion of lacrimal and salivary glands

- _____ (10) innervates blood vessels
- _____ (11) most active when you are lolling in a hammock
- _____ (12) most active when you are running in the Boston Marathon
- _____ (13) gray rami communicantes
- _____ (14) synapse in celiac ganglion
- _____ (15) relates to fear response induced by the amygdala

3. The thoracic splanchnic nerves contain which kind of fibers? (a) preganglionic parasympathetic, (b) postganglionic parasympathetic, (c) preganglionic sympathetic, (d) postganglionic sympathetic.
4. The collateral ganglia contain which kind of cell bodies? (a) postpreganglionic parasympathetic, (b) postganglionic parasympathetic, (c) preganglionic sympathetic, (d) postganglionic sympathetic.
5. Preganglionic sympathetic neurons develop from (a) neural crest, (b) neural tube, (c) alar plate, (d) endoderm.
6. Which of the following is the best way to describe how the ANS is controlled? (a) completely under control of voluntary cerebral cortex, (b) entirely controls itself, (c) completely under control of brain stem, (d) little control by cerebrum, major control by hypothalamus and amygdala, and major control by spinal and peripheral reflexes.

7. The white rami communicantes contain what kind of fibers? (a) preganglionic parasympathetic, (b) postganglionic parasympathetic, (c) preganglionic sympathetic, (d) postganglionic sympathetic.
8. Collateral sympathetic ganglia are involved with the innervation of the (a) abdominal organs, (b) thoracic organs, (c) head, (d) arrector pili, (e) all of these.

Short Answer Essay Questions

9. Is the visceral sensory nervous system part of the autonomic nervous system? Explain your answer.
10. (a) Describe the anatomical relationship of the white and gray rami communicantes to a spinal nerve, and to the dorsal and ventral rami. (b) Why are gray rami communicantes gray?
11. What effect does sympathetic activation have on each of the following structures? Sweat glands, pupils of the eye, adrenal medulla, heart, lungs, blood vessels of skeletal muscles, blood vessels of digestive viscera, salivary glands.
12. Which of the effects listed in question 11 would be reversed by parasympathetic activity?
13. A friend asks you how the parasympathetic division, which comes only from cranial and sacral regions, is able to innervate organs in the thorax and abdomen. How would you answer that question?
14. What manifestations of decreased ANS efficiency are seen in elderly people?
15. The students in anatomy class were having difficulty understanding what kind of cell bodies are located in the autonomic ganglia. Frustrated by being asked this same question repeatedly, the exasperated teaching assistant stood on a desk and yelled, "Autonomic ganglia always contain the *postganglionic* cell bodies!" Describe how that information enabled the students to work out which type of neuron has cell bodies in the (a) sympathetic trunk ganglia, (b) intramural ganglia, and (c) head ganglia (ciliary, pterygopalatine, submandibular, and otic).
16. Describe the sympathetic pathways to the (a) submandibular salivary gland, (b) bladder, (c) sweat glands in the skin, (d) adrenal medulla, (e) heart, (f) stomach.
17. Describe the parasympathetic pathways to the (a) smooth muscles in the eye, (b) bladder, (c) small intestine.
18. Describe the path of the vagus through the neck, thorax, and abdomen.
19. What structures are innervated by the *sacral* part of the parasympathetic division?
20. How do the somatic motor and visceral motor (ANS) pathways differ anatomically and functionally?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. A 1-year-old infant has a swollen abdomen and is continually constipated. On examination, a mass is felt over the distal colon, and X-ray findings show the colon to be greatly distended in that region. From the information in this chapter, identify one possible cause for these symptoms.
2. Roweena, a high-powered marketing executive, develops a stomach ulcer. She complains of a deep abdominal pain that she cannot quite locate, plus superficial pain on her abdominal wall. Exactly where on the abdominal wall is the superficial pain most likely to be located? (Refer to Figure 15.9.)
3. Constipated people often have hardened feces that can tear the inner lining of the rectum and anus during defecation. Those with tears in the skin of the anus complain of sharp pain, whereas those with tears higher up in the intestinal mucosa do not complain of such pain. How do you explain this difference?
4. A woman with a history of kidney infections was feeling pain in the skin of the lower part of her abdomen and even in her thighs. Does this make sense? Why or why not?
5. Which clinical condition has the classical symptoms of blue fingertips that later turn bright red?
6. Why does a person with a spinal cord injury have no deficits in digestive function?
7. Suppose that a mad scientist seeking to invent a death ray produces a beam that destroys a person's ciliary, pterygopalatine, and submandibular ganglia (and nothing else). List all the signs that would be apparent in the victim. Would the victim die, or would the scientist have to go back to the laboratory to try again?
8. Job-related stress is a concern for people in many occupations. One response to stress is an increase in sympathetic nerve activity. What are some health-related problems that can result from chronic sympathetic stimulation?



Access everything you need to practice, review, and self-assess for both your anatomy lecture and lab courses at **MasteringA&P™** (www.masteringaandp.com). There, you'll find powerful online resources—including chapter quizzes and tests, games and activities, A&P Flix animations with quizzes, **Practice Anatomy Lab™**, and more—to help you get a better grade in your course.

16 The Special Senses

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Section through the human retina showing bipolar neurons (red), rod cells (white), and yellow cone cells (colored SEM).

Segmentation By \ Belal Shams AlDin

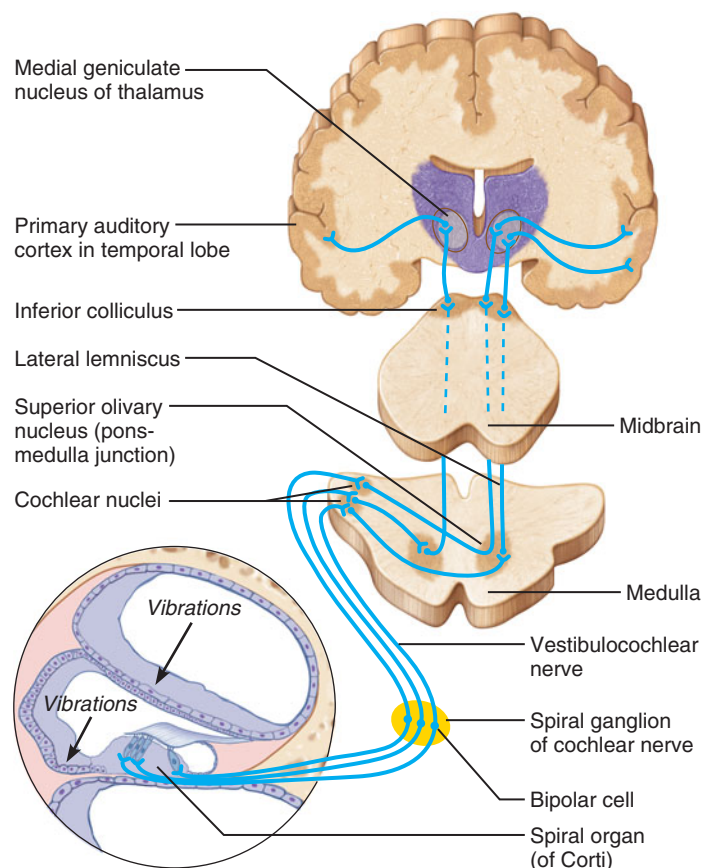


FIGURE 16.24 The auditory pathway. This simplified diagram shows only the pathway from the right ear.

receptor cells that measure *rotational (angular) acceleration* of the head, as occurs when a figure skater spins or a gymnast does a flip. Each crista has an epithelium on its top that, like the maculae, contains *supporting cells* and receptor *hair cells*. The “hairs” of these hair cells project into a tall, jellylike mass that resembles a pointed cap, the **cupula** (ku’pu-lah; “little barrel”); the basal parts of the hair cells synapse with fibers of the vestibular nerve.

Because the three semicircular ducts lie in three different planes, each crista responds to head rotation in a different plane of space. When the head starts to rotate, the endolymph in the semicircular duct lags behind at first, pushing on the cupula and bending the hairs (Figure 16.23c). As their hairs bend, the hair cells depolarize and change the pattern of impulses carried by vestibular nerve fibers to the brain.

check your understanding

15. What is the difference between the membranous labyrinth and the bony labyrinth of the internal ear?
16. Where is perilymph located within the cochlea?
17. Where in the cochlear duct is each of these membranes located: vestibular membrane, the basilar membrane, the tectorial membrane?

Vibrations in which membrane stimulate the hair cells of the spiral organ?

18. Which sensory receptors monitor stationary head position and linear movements of the head? Where are these receptors located?

For answers, see Appendix B.

Auditory and Equilibrium Pathways

- Describe the pathways taken by auditory and equilibrium information through the brain.

As is the case for all sensory information, information on equilibrium and hearing travels to the brain for processing and integration.

The ascending **auditory pathway** transmits auditory information primarily from the cochlear receptors of the inner hair cells to the cerebral cortex (Figure 16.24). First, impulses pass through the cochlear nerve to the **cochlear nuclei** in the medulla. From there, some neurons project to the **superior olivary nuclei**, which lie at the junction of the medulla and pons. Beyond this, the axons ascend in the **lateral lemniscus** (a fiber tract) to the **inferior colliculus** (the auditory reflex center in the midbrain), which projects to the **medial geniculate nucleus** of the thalamus. Axons of the thalamic neurons then project to the primary auditory cortex, which provides conscious awareness of sound. The auditory pathway is unusual in that not all of its fibers cross over to the other side of the brain. Therefore, each primary auditory cortex receives impulses from both ears. Clinically, this phenomenon makes identifying damage to the primary auditory cortex on one side difficult, because such damage produces only a minimal loss of hearing.

The superior olivary nuclei and inferior colliculus are not merely relay stations along the auditory pathway, but perform important functions of their own. For example, both these structures participate in the localization of sounds. For more on the function of the inferior colliculus, refer to p. 388.

The **equilibrium pathway** transmits information on the position and movements of the head via the vestibular nerve to the brain stem. Equilibrium is the only special sense for which most information goes to the *lower* brain centers—which are primarily reflex centers—rather than to the “thinking” cerebral cortex. This pathway reflects the fact that the responses to a loss of balance, such as stumbling, must be rapid and reflexive: In the time it takes you to “think about” correcting a fall, you would hit the ground. The vestibular nuclei in the medulla (shown in Figure 13.12c and discussed on p. 384) and the cerebellum (p. 388) are the major brain centers for processing information on equilibrium. A minor pathway to the cerebral cortex provides conscious awareness of the position and movements of the head. In this minor pathway, vestibular nerve fibers project to the vestibular nuclei, then to the thalamus, and then to the posterior insula of the cerebrum.

eye movements are uncoordinated, and often only one eye is used at a time. By 3 months, however, infants can focus an image on the retina's fovea centralis for sharp vision, and babies can follow moving objects with their eyes. By the age of 6 months, depth perception is present, color vision is well developed, and the earlier hyperopia is almost gone.

As a person ages, the lens loses its clarity and becomes discolored, and it begins to scatter light (the resulting glare is why older people should look slightly away from oncoming headlights while driving at night). The dilator muscles of the iris become less efficient, so the pupils stay partly constricted. All these changes decrease the amount of light reaching the retina, such that visual acuity is dramatically lower in people over 70. In addition, elderly individuals are susceptible to conditions that cause blindness, such as glaucoma, retinal detachment, diabetes mellitus, and age-related macular degeneration.

Newborn infants can hear, but their early responses to sounds are mostly reflexive—for example, crying and clenching the eyelids in response to a startling noise. Infants can hear low-pitched and middle-pitched sounds at birth, but the ability to hear high-pitched sounds is a postnatal development. By the third or fourth month, infants can localize sounds and will turn to the voices of family members. By 12 months, babies know all the sounds of their native

language, and critical listening begins in toddlers as they learn to speak.

Congenital structural abnormalities of the external ear, including partly or fully missing pinnae and closed or absent auditory canals, are fairly common; less common is sensorineural deafness due to maternal rubella infections during pregnancy. Except for the common ear infections of childhood, few problems usually affect the ears until old age. By about age 60, however, deterioration of the spiral organ becomes noticeable. Humans are born with about 20,000 hair cells in each ear, but they are gradually lost. The ability to hear high-pitched sounds fades first. This gradual loss of hearing with age is called **presbycusis** (pres"bī-ku'sis), literally, "old hearing." It is the most common type of sensorineural deafness. Although it is considered a disability of old age, it is becoming more common in younger people as the modern world grows noisier.

In mammals, the hair cells of the internal ear of both hearing and equilibrium do not regenerate naturally. However, gene therapy techniques have induced new hair cell formation. The gene *Math1*, introduced into the inner ear fluid of adult guinea pigs, resulted in the growth of new hair cells. *Math1* encodes for a protein that induces an immature ear cell to become a hair cell. This research could lead to the treatment of many types of hearing loss.

RELATED CLINICAL TERMS

CONGENITAL DEAFNESS One of every 500–1000 children is born deaf because of such physical factors as an immobile stapes, overproduction of perilymph, and various malformations of the middle and internal ear. The ultimate causes of congenital deafness are less well understood, though it can result from maternal mumps, syphilis, or rubella during pregnancy. Many congenital cases are genetically based, and at least four different genes have been identified that, when mutated, cause deafness.

OPHTHALMOLOGY (of"thal-mol'o-je; "eye study") The study of the eye and eye diseases. An *ophthalmologist* is a medical doctor whose specialty is treating eye disorders. By contrast, an *optometrist* is a licensed nonphysician who measures vision and prescribes corrective lenses.

OTITIS EXTERNA (SWIMMER'S EAR) Inflammation and infection of the external acoustic meatus, caused by bacteria or fungi that enter the canal from outside, especially when the canal is moist.

OTORHINOLARYNGOLOGY (o"to-ri"no-lar"ing-gol'o-je) The study of the ear, nose, and larynx and the diseases of these body regions.

SCOTOMA (sko-to'mah; *scoto* = darkness) A blind spot in the visual field other than the normal blind spot caused by the optic disc; often reflects the presence of a brain tumor pressing on nerve fibers along the visual pathway.

TINNITUS (tī-ni'-tus) Persistent noise—a ringing, whistling, humming, buzzing, or screeching—that seems to come from the ears in 10% to 20% of all elderly people, causing great distress and annoyance. It often first appears after a loud noise or an injury to the head or cochlea. Recent evidence suggests that tinnitus is analogous to phantom limb pain (see p. 421)—it is a "phantom cochlear noise" caused by destruction of some neurons along the auditory pathway. With the other neurons of this pathway now deprived of their normal input, nearby axons grow in and reinnervate these neurons, and the CNS interprets background signals from the new axons as noise. Treatments include masking the noise with soothing sounds, counseling, and biofeedback; drugs are largely unsuccessful.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics of Chapter 16.

PAL = Practice Anatomy Lab™

The Chemical Senses: Taste and Smell (pp. 483–486)

Taste (Gustation) (p. 483–484)

1. Most taste buds are on the tongue, in the epithelium of fungiform and circumvallate papillae.

2. Taste buds contain gustatory epithelial cells and basal epithelial cells that replace damaged gustatory cells. The gustatory epithelial cells are excited when taste-stimulating chemicals bind to their microvilli.
3. The five basic qualities of taste are sweet, sour, salty, bitter, and umami.

4. The sense of taste is served by cranial nerves VII, IX, and X, which send impulses to the medulla. From there, impulses travel to the thalamus and the taste area of the cerebral cortex.

Smell (Olfaction) (pp. 484–485)

5. The olfactory epithelium is located in the roof of the nasal cavity. This epithelium contains olfactory sensory neurons, supporting epithelial cells, and basal epithelial cells.
6. The olfactory sensory neurons are ciliated bipolar neurons. Odor molecules bind to the cilia, exciting the neurons. Axons of these neurons form the filaments of the olfactory nerve (cranial nerve I).
7. Olfactory nerve axons transmit impulses to the olfactory bulb. Here, these axons synapse with mitral cells in structures called glomeruli.
8. After receiving input from the olfactory sensory neurons, the mitral cells send this olfactory information through the olfactory tract to the olfactory cortex and limbic system.

Disorders of the Chemical Senses (p. 485)

9. Disorders of smell include anosmia (inability to smell) and unicornate fits (smell hallucinations).

Embryonic Development of the Chemical Senses (p. 485–486)

10. The olfactory epithelium and taste buds develop from the epithelia on the face and mouth/pharynx, respectively.

The Eye and Vision (pp. 486–499)

11. The eye is located in the bony orbit and is cushioned by fat. The cone-shaped orbit also contains nerves, vessels, and extrinsic muscles of the eye.

Accessory Structures of the Eye (pp. 486–489)

12. Eyebrows shade and protect the eyes.
13. Eyelids protect and lubricate the eyes by reflexive blinking. Each eyelid contains a supporting tarsal plate, the roots of the eyelashes, and tarsal and ciliary glands. Muscles in the eyelids include the levator palpebrae superioris, which opens the eye, and the orbicularis oculi, which closes the eye.
14. The conjunctiva is a mucosa that covers the inner surface of the eyelids (palpebral conjunctiva) and the white of the eye (bulbar conjunctiva). Its mucus lubricates the eye surface.
15. The lacrimal gland secretes lacrimal fluid (tears), which spreads medially across the eye surface and drains into the nasal cavity through the lacrimal canaliculi, lacrimal sac, and nasolacrimal duct.
16. The six extrinsic eye muscles are the lateral and medial rectus (which turn the eye laterally and medially, respectively); the superior and inferior rectus (which elevate and depress the eye, respectively, but also turn it medially); and the superior and inferior obliques (which depress and elevate the eye, respectively, but also turn it laterally).

Anatomy of the Eyeball (pp. 489–495)

17. The wall of the eye has three layers. The most external, fibrous layer consists of the posterior sclera and the anterior cornea. The tough sclera protects the eye and gives it shape. The cornea is the clear window through which light enters the eye.
18. The middle, pigmented vascular layer consists of the choroid, the ciliary body, and the iris. The choroid provides nutrients to the retina's photoreceptors and prevents the scattering of light within

the eye. The ciliary body contains smooth ciliary muscles that control the shape of the lens and ciliary processes that secrete aqueous humor. The iris contains smooth muscle that changes the size of the pupil.

19. The sensory layer contains the retina and the optic nerve. The retina consists of an outer pigmented layer and an inner neural layer. The neural layer contains photoreceptors (rod and cone cells) and other types of neurons. Light influences the photoreceptors, which signal bipolar cells, which signal ganglion cells. The axons of ganglion neurons run along the inner retinal surface toward the optic disc, forming the optic nerve.
20. The outer segments of the rods and cones contain light-absorbing pigment in membrane-covered discs. Light modifies this pigment to initiate the flow of signals through the visual pathway.
21. Two important spots on the posterior retinal wall are (1) the macula lutea with its fovea centralis (area of highest visual acuity) and (2) the optic disc (blind spot), where axons of ganglion cells form the optic nerve.
22. The outer third of the retina (photoreceptors) is nourished by capillaries in the choroid, whereas the inner two-thirds is supplied by the central vessels of the retina.
23. The posterior segment of the eye, posterior to the lens, contains the gel-like vitreous humor. The anterior segment, anterior to the lens, is divided into anterior and posterior chambers by the iris. The anterior segment is filled with aqueous humor, which continually forms at the ciliary processes in the posterior chamber, flows into the anterior chamber, and drains into the scleral venous sinus.
24. The biconvex lens helps to focus light. It is suspended in the eye by the ciliary zonule attached to the ciliary body. Tension in the zonule resists the lens's natural tendency to round up.

The Eye as an Optical Device (pp. 495–496)

25. As it enters the eye, light is bent by the cornea and the lens and focused on the retina. The cornea accounts for most of this refraction, but the lens allows focusing on objects at different distances.
26. The resting eye is set for distance vision. Focusing on near objects requires accommodation (allowing the lens to round as ciliary muscles release tension on the ciliary zonule). The pupils also constrict. Both these actions are controlled by parasympathetic fibers in the oculomotor nerve.
27. Eye-focusing disorders include myopia (nearsightedness), hyperopia (farsightedness), presbyopia (loss of lens elasticity with age).

Visual Pathways (pp. 496–499)

28. The visual pathway to the brain begins with some processing of visual information in the retina. From there, ganglion cell axons carry impulses via the optic nerve, optic chiasma, and optic tract to the lateral geniculate nucleus of the thalamus. Thalamic neurons project to the primary visual cortex.
29. At the optic chiasma, axons from the medial halves of the retinas decussate. This phenomenon provides each visual cortex with information on the opposite half of the visual field as seen by both eyes. The visual cortex compares the views from the two eyes and generates depth perception.

Disorders of the Eye and Vision (p. 499)

30. Three blinding disorders were considered, two that damage the retina (age-related macular degeneration and retinopathy of prematurity) and one that damages the cornea (trachoma).

Embryonic Development of the Eye (p. 499)

31. Each eye starts as an optic vesicle, a lateral outpocketing of the embryonic diencephalon. This vesicle then invaginates to form the optic cup, which becomes the retina. The overlying ectoderm folds to form the lens. The fibrous and vascular layers derive almost entirely from mesenchyme around the optic cups.

The Ear: Hearing and Equilibrium (pp. 499–509)**The External Ear (p. 501)**

32. The auricle and external acoustic meatus constitute the external ear, which acts to gather sound waves. The tympanic membrane (eardrum) transmits sound vibrations to the middle ear.

The Middle Ear (pp. 501–502)

33. The middle ear is a small cavity within the temporal bone. Its boundaries are the eardrum laterally, the bony wall of the inner ear medially, a bony roof, a thin bony floor, a posterior wall that opens into the mastoid antrum, and an anterior wall that opens into the pharyngotympanic tube.
34. The pharyngotympanic tube, which consists of bone and cartilage, runs to the pharynx and equalizes air pressure across the eardrum.
35. The auditory ossicles (malleus, incus, and stapes), which help to amplify sound, span the middle ear cavity and transmit sound vibrations from the eardrum to the oval window. The tiny tensor tympani and stapedius muscles dampen the vibrations of very loud sounds.

The Internal Ear (pp. 502–508)

36. The internal ear consists of the bony labyrinth (semicircular canals, vestibule, and cochlea), which is a chamber that contains the membranous labyrinth (semicircular ducts, utricle and saccule, and cochlear duct). The bony labyrinth contains perilymph, whereas the membranous labyrinth contains endolymph.
37. The coiled cochlea is divided into three parts (scalae). Running through its center is the cochlear duct (scala media), which contains the spiral organ. The latter is an epithelium that lies on the basilar membrane and contains the hair cells (receptors for hearing). The other two parts of the cochlea are the scala vestibuli and the scala tympani parts of the bony labyrinth.
38. In the mechanism of hearing, sound vibrations transmitted to the stapes vibrate the fluids in the cochlea. This vibrates the basilar membrane and spiral organ, and in turn bends the hairs of the receptor cells, whose tips are anchored in a nonmoving tectorial membrane. Bending of the hairs produces impulses in the cochlear nerve.
39. The saccule and utricle each contain a macula, a spot of receptor epithelium that monitors static equilibrium and linear acceleration. A macula contains hair cells whose “hairs” are anchored in an overlying otolithic membrane. Forces on the otolithic membrane, caused by gravity and linear acceleration of the head, bend the hairs and initiate impulses in the vestibular nerve.

40. The semicircular ducts lie in three planes of space (anterior vertical, posterior vertical, and lateral horizontal). Their cristae ampullares contain hair cells that monitor rotational acceleration. The “hairs” of these cells are anchored in an overlying cupula. Forces on the cupula, caused by rotational acceleration of the head, bend the hairs and initiate impulses in the vestibular nerve.

Auditory and Equilibrium Pathways (p. 508)

41. Impulses generated by the hearing receptors travel along the cochlear nerve to the cochlear nuclei in the medulla. From there, auditory information passes through several nuclei in the brain stem (superior olivary, inferior colliculus) to the medial geniculate nucleus of the thalamus and cerebral auditory cortex.
42. Impulses generated by the equilibrium receptors travel along the vestibular nerve to the vestibular nuclei and the cerebellum. These brain centers initiate responses that maintain balance. There is also a minor equilibrium pathway to the posterior insula of the cerebral cortex.

Disorders of Equilibrium and Hearing (p. 509)

43. Motion sickness, brought on by particular movements, causes nausea and vomiting. Ménière’s syndrome is an overstimulation of the hearing and equilibrium receptors caused by an excess of endolymph in the membranous labyrinth.
44. Conduction deafness results from interference with the conduction of sound vibrations to the internal ear. Sensorineural deafness reflects damage to auditory receptor cells or neural pathways.

Embryonic Development of the Ear (p. 509)

45. The membranous labyrinth develops from the otic placode, a thickening of ectoderm superficial to the hindbrain.
46. A pouch from the pharynx becomes the middle ear cavity and the pharyngotympanic tube. The outer ear is formed by an external branchial groove (external acoustic meatus) and by swellings around this groove (auricle).

The Special Senses Throughout Life (pp. 509–511)

47. The chemical senses are sharpest at birth and decline with age as the replacement of receptor cells slows.
48. The eye is farsighted (farsighted) at birth. Depth perception, eye coordination, and color vision develop during early childhood. With age, the lens loses elasticity and clarity, and visual acuity declines. Eye problems that may develop with age are presbyopia, cataracts, glaucoma, retinal detachment, and age-related macular degeneration.
49. Initially, infants respond to sound only in a reflexive manner. By 5 months, infants can locate sound. Critical listening develops in toddlers. Obvious age-related loss of hearing (presbycusis) occurs in a person’s 60s and 70s.

PAL Human Cadaver/Nervous System/Special Senses

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Sensory impulses transmitted over the facial, glossopharyngeal, and vagus nerves are involved in the special sense of (a) taste, (b) vision, (c) equilibrium, (d) smell.

2. The part of the fibrous layer of the eye that is white, tough, and opaque is the (a) choroid, (b) cornea, (c) retina, (d) sclera.
3. The transmission of sound vibrations through the internal ear occurs chiefly through (a) nerve fibers, (b) air, (c) fluid, (d) bone.

4. Of the neurons in the retina, which form the optic nerve? (a) bipolar neurons, (b) ganglion neurons, (c) cone cells, (d) horizontal neurons.
5. Blocking the scleral venous sinus might result in (a) a sty, (b) glaucoma, (c) conjunctivitis, (d) Ménière's syndrome, (e) a chalazion.
6. Conduction of sound from the middle ear to the internal ear occurs via vibration of the (a) malleus against the tympanic membrane, (b) stapes in the oval window, (c) incus in the round window, (d) tympanic membrane against the stapes.
7. The structure that allows the air pressure in the middle ear to be equalized with that of the outside air is the (a) cochlear duct, (b) mastoid air cells, (c) endolymph, (d) tympanic membrane, (e) pharyngotympanic tube.
8. The receptors for static equilibrium that report the position of the head in space relative to the pull of gravity are in the (a) spiral organ (of Corti), (b) maculae, (c) crista ampullaris, (d) cupulae, (e) joint kinesthetic receptors.
9. Paralysis of a medial rectus muscle would affect (a) accommodation, (b) refraction, (c) depth perception, (d) pupil constriction.
10. A light ray passes through the refractory structures of the eye in this order: (a) vitreous humor, lens, aqueous humor, cornea; (b) cornea, aqueous humor, lens, vitreous humor; (c) cornea, vitreous humor, lens, aqueous humor; (d) lens, aqueous humor, cornea, vitreous humor.
11. The optic disc is the site where (a) more rods than cones occur, (b) the macula lutea is located, (c) only cones occur, (d) the optic nerve exits the eye.
12. Which of these is not a basic taste sensation? (a) bitter, (b) tsunami, (c) sour, (d) sweet.

Short Answer Essay Questions

13. An anatomy student was arguing with his grandfather. Granddad, who believed in folk wisdom, insisted that there are only five senses. The student, however, said that there are at least ten senses. Decide who was right, and then list all the senses you know. (See Table 12.1, p. 350.)
14. (a) What is the precise location of the olfactory epithelium? (b) Trace the pathway of olfactory stimuli from the olfactory epithelium to the cerebral cortex.
15. What and where is the fovea centralis, and why is it important?
16. Name two special senses whose receptor cells are replaced throughout life, and two special senses whose receptor cells are replaced so slowly that there can be no functional regeneration.
17. (a) Describe the embryonic derivation of the retina. (b) Explain how the middle ear cavity forms.
18. Describe some effects of aging on the eye and the ear.
19. Trace the auditory pathway to the cerebral cortex.
20. Compare and contrast the functions of the inferior oblique and superior rectus muscles.
21. (a) What is the difference, if any, between a semicircular canal and semicircular duct? Between the cochlea and cochlear duct? (b) Name the three parts of the membranous labyrinth of the internal ear. Which of these parts is for hearing, and which are for balance?
22. Describe the function and the innervation of both the sphincter and dilator muscles of the pupil (in the iris of the eye).

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Enrique's uncle tells the physician that 3-year-old Enrique gets many "earaches." Upon questioning, the uncle reveals that Enrique has not had a sore throat for a long time and is learning to swim. Does Enrique have otitis media or otitis externa, and does he need ear tubes? Explain your reasoning.
2. Nine children attending the same day-care center developed inflamed eyes and eyelids. What is the most likely cause and name of this condition?
3. Dr. Nakvarati used an instrument to blow a puff of air on Mr. Jefferson's eye during his annual physical examination on his 60th birthday. The eye deformed very little, indicating that the intraocular pressure was too high. What was Mr. Jefferson's probable condition?
4. Lionel suffered a ruptured artery in his middle cranial fossa, and a pool of blood compressed his left optic tract, destroying its axons. What part of the visual field was blinded?
5. Ming, a student in optometry school, felt very sad when she saw some premature babies at the hospital who were born before 25 weeks after conception. She knew that many of these children would soon be blind for life. Explain why.
6. Jan, a senior citizen, developed a constant howling sound in her ear that would not stop. It was very annoying and stressful, and she had to go to counseling to learn how to live with this awful noise.

What was her condition called, and what are some other treatments she might receive for it? (See this chapter's Related Clinical Terms.)

7. Describe the effect on vision of a tumor in the hypothalamus or pituitary gland that compresses the optic chiasma, destroying the axons crossing through this structure.



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The Endocrine System

17

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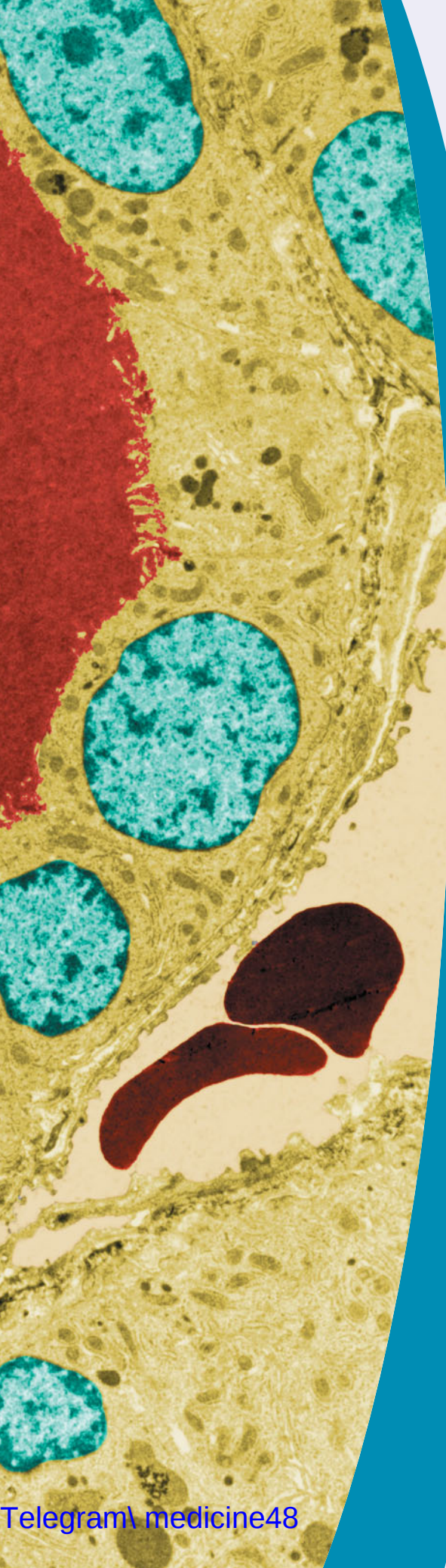
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Portions of thyroid follicles surrounding a fenestrated capillary containing RBC (colored TEM).

The adrenal cortex also shows structural changes with age, but normal rates of glucocorticoid secretion appear to persist as long as an individual is healthy. No age-related changes in the release of the amine hormones epinephrine and norepinephrine by the adrenal medulla have been found.

The synthesis and release of thyroid hormones diminish somewhat with normal aging. Typically, the thyroid follicles are loaded with colloid in the elderly, and fibrosis of the gland occurs. Autoimmune diseases of the thyroid become common, affecting about 5% of older women.

The parathyroid glands change little with age, but a tendency for the concentration of PTH in the blood to increase compensates for a lowered intake of calcium and vitamin D

as the quality of the diet declines. Furthermore, the decline in estrogen secretion after menopause may sensitize women to the bone-demineralizing effects of PTH.

Only growth hormone (GH) from the anterior pituitary, dehydroepiandrosterone (DHEA) from the adrenal cortex, and the sex hormones (estrogens and testosterone) show marked drops in secretion with age. The deterioration of the musculoskeletal, cardiovascular, immune, and other organs that accompany these hormonal declines is discussed elsewhere in this book (see pp. 257, 612, and 631). So closely do the effects of withdrawing these hormones parallel the symptoms of aging that all three have been commercialized as “antiaging drugs” in recent years.

RELATED CLINICAL TERMS

HYPERCALCEMIA Elevated concentrations of calcium ions in the blood caused by either primary hyperparathyroidism or malignancies. In primary hyperparathyroidism, a parathyroid gland spontaneously (usually as a result of a tumor) secretes large amounts of calcium-raising parathyroid hormone. Many different kinds of malignancies also raise blood calcium levels by secreting chemicals that either stimulate osteoclasts to dissolve bone or stimulate calcium resorption in the kidney.

HYPOPHYSECTOMY Surgical removal of the pituitary gland.

PANCREATIC TRANSPLANTATION A procedure performed on people with type 1 diabetes whose lives are threatened by gradually failing kidneys as *microangiopathy of diabetes* (p. 611) destroys the kidney capillaries. The transplanted pancreas secretes insulin and halts the diabetes, and a healthy kidney may be transplanted at the same time to take over for the recipient's failing kidneys. The donated pancreas is placed in the pelvis and sutured to the bladder so that the digestive enzymes it produces can drain into the bladder and be flushed from the body in the urine, instead of irritating the pelvic peritoneum and causing peritonitis. The recipient must take immunosuppressive drugs for life. The success rate for pancreatic transplantation is about 70%. Techniques to transplant only the pancreatic islets have been developed. Islets from a deceased donor are injected into the recipient's liver. Transplanted islets become vascularized and start secreting insulin. Although still experimental, this treatment has met with a moderate degree of success. It also requires that the recipient take immunosuppressive drugs for life.

PHEOCHROMOCYTOMA (fe"o-kro"mo-si"to'mah; “dusky color tumor”) Tumor of the chromaffin cells of the adrenal medulla; results in

excessive secretion of the hormones epinephrine and norepinephrine, which produces the symptoms of prolonged sympathetic response (especially hypertension).

PROLACTINOMA (oma = tumor) The most common type of pituitary gland tumor, characterized by a hypersecretion of prolactin, excessive secretion of milk, and menstrual disturbances in women. In men, it causes milk production, a loss of libido, and impotence.

PSYCHOSOCIAL DWARFISM Dwarfism (and failure to thrive) resulting from childhood stress and emotional disorders that suppress the hypothalamic release of growth hormone–releasing hormone and thus anterior pituitary secretion of GH.

THYROID CANCER The most common malignancy of the endocrine glands, affecting about 1% of all people, typically between the ages of 25 and 65; characterized by firm, fixed nodules in the thyroid. Incidence is increasing, especially among individuals who had external irradiation of the head and neck when young. Treatment of this highly curable cancer involves removing some or all of the thyroid, then administering a radioactive form of iodine, which is actively taken up by the remaining thyroid follicular cells (normal and cancerous). The sequestered radioactive iodine then kills the cancer cells with a minimum of harm to nonthyroidal tissues.

THYROID STORM (THYROID CRISIS) A sudden and dangerous increase in the effects of thyroid hormone resulting from excessive amounts of TH in the circulation; metabolic rate is greatly increased, as indicated by fever, rapid heart rate, high blood pressure, nervousness, and tremors. Precipitating factors include stressful situations, excessive intake of TH supplements, and trauma to the thyroid gland.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 17.

PAL = Practice Anatomy Lab™

1. Endocrine organs are ductless glands that release hormones into the blood or lymph.
2. Hormones are messenger molecules that travel in the circulatory vessels and signal physiological changes in target cells.

3. Hormonally regulated processes include reproduction, growth, mobilization of body defenses against stress, maintenance of the proper chemistry of the blood and body fluids, and regulation of cellular metabolism.

Overview (pp. 516–518)

Endocrine Organs (p. 516)

4. The endocrine organs are small and widely separated from one another within the body. The pure endocrine organs are the pituitary,

thyroid, parathyroid, adrenal, and pineal glands. Other organs that contain endocrine cells are the gonads, pancreas, kidney, alimentary canal, heart, thymus, and skin. The hypothalamus of the brain is a neuroendocrine organ.

5. Endocrine organs are richly vascularized.
6. Although most endocrine cells are modified epithelial cells, others are neurons, muscle cells, or fibroblast-like cells.

Hormones (pp. 516–518)

7. Most hormones are either amino acid derivatives (amines, peptides, proteins) or steroids (lipid-based molecules derived from cholesterol).
8. Hormones produce their effects by leaving the capillaries and binding to specific receptor molecules in or on their target cells. Such binding triggers a preprogrammed response in the target cell.
9. Endocrine organs are stimulated to release their hormones by humoral, neural, or hormonal stimuli. Hormonal secretion is controlled by feedback loops.
10. The hypothalamus of the brain regulates many functions of the endocrine system through the hormones it secretes.

The Major Endocrine Organs (pp. 518–529)

The Pituitary Gland (pp. 518–523)

11. The golf club-shaped pituitary gland is suspended from the diencephalon of the brain by its stalk (infundibulum) and lies in the hypophyseal fossa of the sella turcica of the sphenoid bone. It consists of an anterior lobe (adenohypophysis) and a posterior lobe (neurohypophysis).
12. The anterior lobe has three parts: pars distalis, pars intermedia, and pars tuberalis. The posterior lobe has two parts: pars nervosa and infundibulum.
13. The pituitary gland receives its rich blood supply from the superior and inferior hypophyseal arteries.
14. The largest part of the anterior lobe is the pars distalis. Its five cell types secrete seven protein hormones. Four of the hormones secreted are tropic hormones (TSH, ACTH, FSH, LH) that influence the secretion of other endocrine glands; three others directly influence nonendocrine target tissues.
15. The hormones secreted by the anterior lobe and their functions are as follows. Growth hormone (GH), secreted by somatotrophic cells, stimulates growth of the body and skeleton. Thyroid-stimulating hormone (TSH), produced by thyrotrophic cells, stimulates secretion of the thyroid gland. Adrenocorticotrophic hormone (ACTH), which stimulates the secretion of hormones from the adrenal cortex, and melanocyte-stimulating hormone (MSH), whose function is uncertain, are secreted by corticotrophic cells. Follicle-stimulating hormone (FSH) and luteinizing hormone (LH), produced by gonadotrophic cells, signal the maturation of sex cells and the secretion of sex hormones. Prolactin, secreted by prolactin cells, stimulates milk production in breast tissue.
16. The hypothalamus of the brain controls the secretion of hormones from the anterior lobe. First, certain hypothalamic neurons make releasing hormones and inhibiting hormones, which they secrete into a primary capillary plexus in the median eminence. These hormones then travel through hypophyseal portal veins to a secondary capillary plexus in the pars distalis. They leave this plexus to signal

the anterior lobe cells to secrete their hormones, which then enter the secondary capillary plexus and travel to their target cells throughout the body.

17. The posterior lobe which consists of nervous tissue, contains the hypothalamic-hypophyseal axon tract. The cell bodies of the neurons that form this tract are located in the paraventricular and supraoptic nuclei of the hypothalamus. These neurons synthesize oxytocin and ADH (vasopressin), respectively, and store them in their axon terminals in the pars nervosa. Here, the stored hormones are released into capillaries when the neurons fire.
18. The posterior lobe hormones have the following functions: ADH increases resorption of water from the urine and raises blood pressure, and oxytocin induces labor and ejection of milk from the breasts. Both these hormones are involved with social bonding.

The Thyroid Gland (pp. 523–524)

19. The thyroid gland, which lies on the superior trachea, consists of spherical follicles covered by epithelial follicle cells and separated by a capillary-rich connective tissue. The follicles are filled with a colloid of thyroglobulin, a storage protein containing thyroid hormone.
20. Thyroid hormone (TH), which contains iodine and increases basal metabolic rate, is made continuously by follicular cells and stored within the follicles until TSH from the pituitary gland signals the follicular cells to reclaim the TH and secrete it into the extrafollicular capillaries.
21. Parafollicular cells protrude from the thyroid follicles and secrete the hormone calcitonin, which can lower blood calcium concentrations in children.

The Parathyroid Glands (pp. 524–525)

22. Several pairs of parathyroid glands lie on the dorsal aspect of the thyroid gland. Their parathyroid cells are arranged in thick, branching cords and secrete parathyroid hormone, which raises low blood calcium levels.

The Adrenal (Suprarenal) Glands (pp. 525–527)

23. The paired adrenal glands lie on the superior surface of each kidney. Each adrenal gland has two distinct parts, an outer cortex and an inner medulla.
24. The adrenal medulla consists of spherical clusters (and some branching cords) of chromaffin cells. Upon sympathetic stimulation, these cells secrete epinephrine and norepinephrine into the blood—the surge of adrenaline that is experienced during fight-or-flight situations.
25. The adrenal cortex has three layers: outer zona glomerulosa, middle zona fasciculata, and inner zona reticularis; the name of each zone describes its histological structure.
26. The steroid hormones secreted by the adrenal cortex (corticosteroids) include mineralocorticoids (mostly from the zona glomerulosa), glucocorticoids (mostly from the zona fasciculata and reticularis), and the androgen DHEA (from the zona reticularis). Mineralocorticoids (mainly aldosterone) conserve water and sodium by increasing resorption of these substances by the kidney. Glucocorticoids (mainly cortisol) help the body cope with stress by stabilizing blood glucose levels; in large quantities they also inhibit inflammation and the immune system. The functions of DHEA are unclear.

The Pineal Gland (p. 528)

27. The pineal gland, on the roof of the diencephalon, contains pinealocytes, which cluster into spherical clumps and cords separated by dense particles of calcium called pineal sand.
28. Pinealocytes secrete the hormone melatonin, which helps regulate circadian rhythms. This secretion is signaled by the suprachiasmatic nucleus of the hypothalamus through a sympathetic pathway.

The Pancreas (p. 528)

29. The endocrine structures in the pancreas are the spherical pancreatic islets. These islets consist of alpha (α), beta (β), delta (Δ) and F (PP) cells arranged in twisting cords.
30. Alpha cells secrete glucagon, which raises blood sugar levels, whereas beta cells secrete insulin, which lowers blood sugar levels.

The Thymus (p. 528)

31. The thymus, an important organ of the immune system, secretes thymic hormones that are essential for the production of T lymphocytes.

The Gonads (pp. 528–529)

32. Various cells in the ovaries and testes secrete steroid sex hormones, estrogens and androgens.

Other Endocrine Structures (p. 529)

33. Some muscle cells in the atria of the heart secrete atrial natriuretic peptide (ANP), which stimulates loss of body fluids and salts through the production of a sodium-rich urine.
34. Endocrine cells are scattered within the epithelium of the digestive tube and other gut-derived organs (respiratory tubes and so on).

These epithelial cells, which have some neuronlike properties, make up the diffuse neuroendocrine system (DNES). There are many classes of DNES cells, some of which secrete hormones that regulate digestion.

35. The placenta secretes hormones of pregnancy, the kidney secretes renin and erythropoietin, and the skin produces vitamin D.

PAL Human Cadaver/Endocrine System**Disorders of the Endocrine System (pp. 529–532)**

36. Most disorders of endocrine glands involve either hypersecretion or hyposecretion of a hormone. *Hypersecretion* of GH leads to gigantism, of TH leads to Graves' disease, and of ACTH or glucocorticoids leads to Cushing's disease. *Hyposecretion* of GH leads to pituitary dwarfism, of TH leads to adult hypothyroidism or cretinism, of glucocorticoids and mineralocorticoids leads to Addison's disease, and of insulin leads to type 1 diabetes mellitus.

The Endocrine System Throughout Life (pp. 532–534)

37. The endocrine glands have diverse developmental origins from all three germ layers. The anterior pituitary arises from ectoderm on the roof of the mouth, and the posterior pituitary arises from the floor of the brain. The endocrine organs in the neck (thyroid, parathyroids, thymus) derive from the endoderm of the pharynx. The pineal gland forms from the ectodermally derived ependyma of the roof of the brain, the adrenal medulla develops from sympathetic trunk ganglia, and the adrenal cortex arises from the mesoderm of the dorsal abdominal wall.
38. The efficiency of some endocrine organs gradually declines as the body ages. The hormones whose secretions decline most are GH, DHEA, estrogens, and testosterone.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. The major stimulus for the release of estrogens is (a) hormonal, (b) humoral, (c) nervous.
2. Choose the correct hormone from the key for each description.

Key:

- | | |
|---|---------------------------------------|
| _____ (1) stimulates cell division in the epiphyseal plates of growing bones | (a) melatonin |
| _____ (2) involved in water balance; causes the kidneys to conserve water | (b) antidiuretic hormone (ADH) |
| _____ (3) stimulates milk production | (c) growth hormone (GH) |
| _____ (4) stimulates milk ejection | (d) luteinizing hormone (LH) |
| _____ (5) tropic hormone that stimulates the gonads to secrete sex hormones | (e) thyroid hormone (TH) |
| _____ (6) increases basal metabolic rate | (f) thyroid-stimulating hormone (TSH) |
| _____ (7) tropic hormone that stimulates the thyroid gland to secrete thyroid hormone | (g) prolactin (PRL) |
| _____ (8) adjusts blood sugar levels and helps the body cope with stress | (h) oxytocin |
| | (i) cortisol |
| | (j) parathyroid hormone (PTH) |

- | |
|---|
| _____ (9) is secreted by the pineal gland |
| _____ (10) increases blood calcium levels |
| _____ (11) is secreted by the posterior lobe of the pituitary (two possible choices) |
| _____ (12) the only steroid hormone in the list |
| 3. The pars distalis of the anterior pituitary does not secrete (a) antidiuretic hormone, (b) growth hormone, (c) gonadotropins, (d) thyroid-stimulating hormone. |
| 4. Endocrine cells secrete either protein hormones or steroid hormones. For each endocrine cell described, indicate whether it produces (a) a protein hormone or (b) a steroid hormone. |
| _____ (1) any endocrine cell in the pars distalis |
| _____ (2) interstitial cell in the testis |
| _____ (3) parathyroid cells in the parathyroid gland |
| _____ (4) zona fasciculata cell |
| _____ (5) follicle cell in the ovary that secretes sex hormones |
| _____ (6) parafollicular cells in the thyroid gland |

5. From the key, choose the best description of histological structure for each of the following glands. More than one answer may be correct.

Key: (a) spherical clusters of cells (d) follicles
(b) parallel cords of cells (e) nervous tissue
(c) branching cords of cells

- ____ (1) pars nervosa of pituitary gland
____ (2) zona glomerulosa of adrenal gland
____ (3) pars distalis of pituitary gland
____ (4) thyroid gland
____ (5) zona fasciculata of adrenal gland

6. The divisions of the posterior pituitary are the (a) anterior lobe and posterior lobe; (b) pars emphasis, metropolis, and hypothesis; (c) pars distalis, tuberalis, and intermedia; (d) pars nervosa and infundibulum; (e) pars glomerulosa, fasciculata, and reticularis.
7. Which of the following cells secrete releasing hormones? (a) neurons, (b) chromaffin cells, (c) cells in the anterior lobe of the pituitary, (d) parafollicular cells.
8. Chromaffin cells occur in the (a) parathyroid gland, (b) pars distalis, (c) pituitary gland, (d) adrenal gland, (e) pineal gland.
9. The anterior lobe of the pituitary gland is the same as the (a) neurohypophysis, (b) pars nervosa, (c) adenohypophysis, (d) hypothalamus.
10. Many endocrine glands produce multiple hormones. Indicate the two hormones from column B that are secreted by each endocrine gland listed in column A.

Column A

- ____, ____ (1) thyroid gland
____, ____ (2) pancreas
____, ____ (3) adrenal gland
____, ____ (4) posterior lobe of the pituitary
____, ____ (5) ovaries

Column B

- (a) glucagon
(b) calcitonin
(c) cortisol
(d) oxytocin
(e) progesterone
(f) norepinephrine
(g) insulin
(h) antidiuretic hormone
(i) estrogen
(j) thyroid hormone

11. Indicate with a check mark which of the organs listed below have some endocrine function.

____ (a) kidney, ____ (b) mammary glands, ____ (c) pancreas,
____ (d) stomach, ____ (e) heart, ____ (f) urinary bladder,
____ (g) respiratory tubes, ____ (h) skin, ____ (i) salivary glands,
____ (j) thymus.

Short Answer Essay Questions

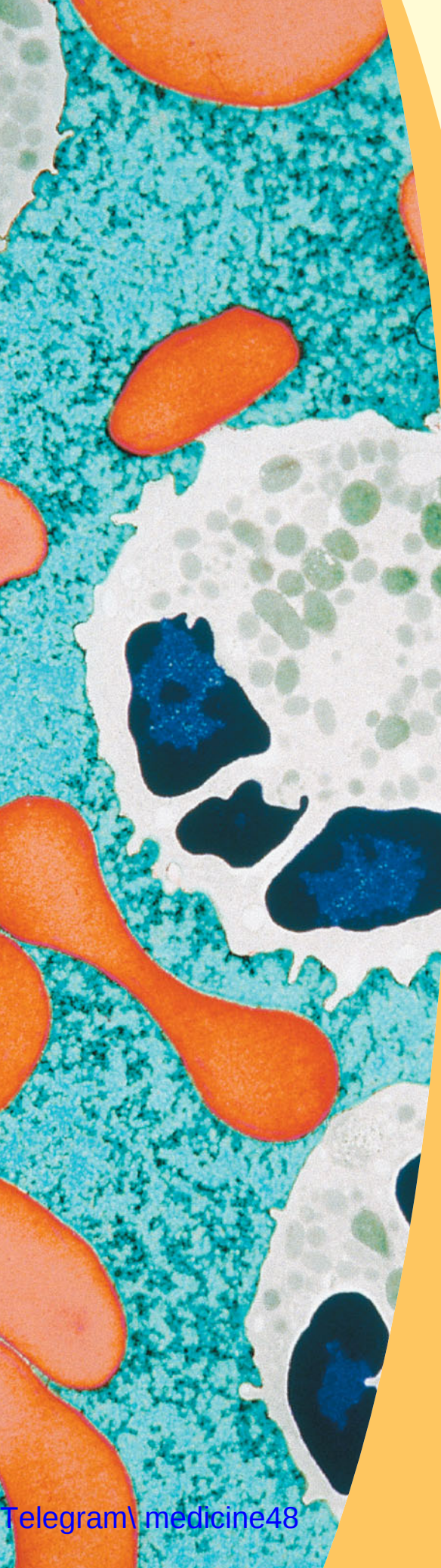
12. (a) Describe where in the body each of the following endocrine glands is located: anterior and posterior lobe of the pituitary, pineal, thyroid, parathyroids, and adrenals. (b) List the hormones secreted by each of these glands.
13. The anterior lobe of the pituitary secretes so many hormones that it is often called the master endocrine organ, but it too has a “master.” What structure controls the release of anterior pituitary hormones?
14. When Joshua explained to his classmate Jennifer that the thyroid gland contains parathyroid cells in its follicles and that the parathyroid cells secrete parathyroid hormone and calcitonin, Jennifer told him he was all mixed up again. Correct Josh’s mistakes.
15. (a) Define hormone. (b) Name a hormone secreted by a muscle cell and a hormone secreted by a neuron.
16. On a realistic drawing of the endocrine glands in the body, such as a photocopy of Figure 17.1, indicate the gland associated with (a) cretinism, (b) diabetes mellitus, (c) acromegaly, (d) secreting thyroid-stimulating hormone, (e) secreting a hormone that regulates the nightly activities of our circadian rhythms, (f) secreting estrogens, (g) secreting DHEA.
17. On a realistic drawing of the endocrine glands in the body, trace the following hormones from their glands of origin all the way to their target organs: (a) vitamin D, (b) glucagon, (c) erythropoietin, (d) oxytocin.
18. On a realistic drawing of the endocrine glands in the body, mark and label the endocrine organs that develop from the (a) roof of the embryonic mouth, (b) floor of the diencephalon, (c) endoderm on the posterior part of the future tongue, (d) endoderm of the pharyngeal pouches (two answers here), (e) neural crest of early sympathetic trunk ganglia.
19. Compare and contrast the functions of both sets of capillaries in the hypophyseal portal system.
20. List the hormones secreted by each of the three zones of the adrenal cortex.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. The brain senses when a person is in a stressful situation, and the hypothalamus responds by secreting a releasing hormone called corticotropin-releasing hormone, which, through a sequence of events, helps the body to deal with the stressful situation. Outline this entire sequence, starting with corticotropin-releasing hormone and ending with the release of cortisol. (As you do this, be sure to trace the hormones through the hypophyseal portal system and out of the pituitary gland.)
2. Jeremy, a 5-year-old boy, has been growing by leaps and bounds such that his height is 70% above normal for his age group. A CT scan reveals a pituitary tumor. (a) What hormone is being secreted in excess? (b) What condition will Jeremy exhibit if corrective measures are not taken?
3. An accident victim who had not been wearing a seat belt received trauma to his forehead when he was thrown against the windshield. The physicians in the emergency room worried that his brain stem may have been driven inferiorly through the foramen magnum. To help assess this, they quickly took a standard X-ray film of his head and searched for the position of the pineal gland. How could anyone expect to find this tiny, boneless gland in a radiograph?
4. Mrs. Giardino had an abnormally high concentration of calcium in her blood, and her physicians were certain she had a tumor of the parathyroid gland. However, when surgery was performed on her neck, the surgeon could not find the parathyroid glands at all. Where should the surgeon look next to find the tumorous parathyroid gland?
5. Explain how endocrine disorders produced the physical characteristics described: (a) obesity in a man with hypothyroidism, (b) small stature and gigantism in people with pituitary disorders, (c) facial hair on a woman with an adrenal tumor, and (d) protrusion of the eyes in a person with Graves' disease.
6. For what therapeutic purposes would pharmaceutical companies seek to design drugs that either mimic atrial natriuretic peptide (ANP) or slow the rate at which ANP is broken down in the body?



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The Blood Throughout Life 550

This chapter and the next three discuss the **circulatory system**, which is subdivided into the **cardiovascular system** (the blood, the heart, and the blood vessels: Chapters 18–20) and the **lymphatic system** (vessels that carry a fluid called lymph: Chapter 21). This chapter is devoted to **blood**, the fluid in the vessels of the cardiovascular system.

Blood is the river of life that surges within us, transporting nearly everything that must be carried from one place to another in the body. For thousands of years, blood was considered magical, an elixir that held the mystical force of life, because when it drained from the body, life departed as well. Today, blood retains an important role in clinical medicine. Blood carries molecular evidence of the body's activities, and examination of blood is essential in clinical assessment. Blood tests are used to screen for evidence of disease, recreational substance use, and nutritional status.

Blood circulation is initiated by the pumping action of the heart. Blood leaves the heart in *arteries*, which branch repeatedly

◀ Blood cells, erythrocytes, and granulocytes (colored TEM).

low-level hematopoiesis during month 3. Bone marrow becomes the major hematopoietic organ in month 7 of development and is the only hematopoietic organ postnatally. Should a severe need for blood cell production arise, however, the liver and spleen may resume their blood-cell-forming roles, even in adults.

The most common diseases of the blood that appear with aging are chronic leukemias, anemias, and clotting disorders. However, these and most other age-related blood disorders are usually precipitated by disorders of the heart, blood vessels, or immune system. For example, the increased incidence of leukemias in old age is believed to result from the waning ability of the immune system to destroy cancer cells, and the

formation of abnormal thrombi and emboli reflects the progression of atherosclerosis, which roughens the linings of arterial walls.

check your understanding

- List the symptoms of anemia. What component of blood is affected by this disorder?
- What are the major hematopoietic organs in the fetus before month 7?
- Why do cord-blood transplant recipients experience lower rates of tissue rejection?

For answers, see Appendix B.

RELATED CLINICAL TERMS

BONE MARROW BIOPSY Procedure for obtaining a sample of bone marrow, usually using a needle to aspirate marrow from the sternum or the iliac bone. The marrow is examined to diagnose disorders of blood cell formation, leukemia, infections, and types of anemia resulting from damage to, or failure of, the marrow.

EMBOLUS Any abnormal mass carried freely in the bloodstream; may be a blood clot, air bubbles, fat masses, clumps of cells, or pieces of tissue. Blood clots are the most common kind of emboli, but *fat emboli*, which enter the blood from the bone marrow following a bone fracture, are also common. *Bacterial emboli* (clusters of bacteria) can occur during blood poisoning. Air bubbles can enter the

bloodstream when a central intravenous line is accidentally disconnected, producing an air embolism.

HEMOPHILIA An inherited disease caused by the lack of, or a reduced amount of, a clotting factor, resulting in blood that does not clot normally. People with hemophilia bleed longer and thus can suffer from excessive blood loss when injured. Replacement clotting factor may be administered intravenously following an injury or as a preventive treatment.

HEMORRHAGE (hem'ð-rij; "blood bursting forth") Any abnormal discharge of blood out of a vessel; bleeding.

CHAPTER SUMMARY

- The circulatory system is subdivided into the cardiovascular system (heart, blood vessels, and blood) and the lymphatic system (lymphatic vessels and lymph).
- Blood carries respiratory gases and nutrients to body tissues and picks up waste products from body tissues. Blood also transports hormones and defense cells to target tissues and regulates body temperature.

Composition of Blood (pp. 540–546)

- Blood consists of plasma and formed elements (erythrocytes, leukocytes, and platelets). Erythrocytes make up about 45% of blood volume, plasma about 55%, and leukocytes and platelets under 1%.
- The volume percentage of erythrocytes is the hematocrit.

Blood Plasma (pp. 540–541)

- Plasma is a fluid that is 90% water. The remaining 10% consists of nutrients, respiratory gases, salts, hormones, and plasma proteins. Serum is plasma from which the clotting factors have been removed.

Formed Elements (pp. 541–546)

- Blood cells are short-lived and are replenished continuously by new cells from the bone marrow.
- A blood smear is prepared by putting a drop of blood on a glass slide; spreading it to form a film; then drying, preserving, and staining the film. Blood smears are stained with mixtures of two dyes, one acidic, such as eosin, and one basic, such as methylene blue.

- Erythrocytes, the most abundant blood cells, are anucleate, biconcave discs with a diameter of 7–8 μm . Essentially, they are bags of hemoglobin, the oxygen-transporting protein. The main function of erythrocytes is to transport oxygen between the lungs and the body tissues. Erythrocytes live about 120 days in the circulation.
- Leukocytes fight infections in the loose connective tissues outside capillaries, using the bloodstream only as a transport system. They leave capillaries by diapedesis and crawl through the connective tissues to the infection sites. There are only 4800–11,000 leukocytes, compared to about 5 million erythrocytes, in a cubic millimeter of blood.
- The five distinct types of leukocytes are grouped into granulocytes and agranulocytes, according to whether they have distinctive cytoplasmic granules. Granulocytes, which include neutrophils, eosinophils, and basophils, are short-lived cells with distinctive cytoplasmic granules and lobed nuclei. All are phagocytic cells. The agranulocytes are lymphocytes and monocytes.
- Neutrophils, the most abundant leukocytes, have multilobed nuclei. Two types of small granules give their cytoplasm a light purple color in stained blood smears. The function of neutrophils is phagocytosis of bacteria.
- Eosinophils have bilobed nuclei and large, red-staining granules that contain digestive enzymes. They destroy and digest parasites and stop allergic reactions.

13. Basophils are rare leukocytes with bilobed nuclei and large, purple-staining granules full of chemical mediators of inflammation. They mediate the late stages of allergic reactions. Although a distinct cell type, they are functionally similar to mast cells.
14. Lymphocytes or their products attack antigens in the specific immune response. These cells have a sparse, blue-staining cytoplasm and a dense, purple-staining, spherical nucleus. T lymphocytes destroy foreign cells directly, whereas B lymphocytes secrete antibodies that mark foreign cells for phagocytosis.
15. Monocytes, the largest leukocytes, resemble large lymphocytes but have a lighter-staining nucleus that may be kidney-shaped. They transform into macrophages in connective tissues.
16. Platelets are disc-shaped, membrane-enclosed fragments of megakaryocyte cytoplasm that contain several kinds of secretory granules. They plug tears in blood vessels, signal vasoconstriction, help initiate clotting, and then retract the clot and close the tear.

Blood Cell Formation (pp. 546–549)

Bone Marrow as the Site of Hematopoiesis (pp. 546–547)

17. Collectively, bone marrow is the body's second largest organ. Red marrow, located between the trabeculae of spongy bone in the axial skeleton, girdles, and proximal epiphysis of each humerus and femur of adults, actively makes blood cells. Yellow marrow, in the other regions of limb bones of adults, is dormant.
18. Microscopically, bone marrow consists of wide capillaries (sinusoids) snaking through reticular connective tissue. The latter contains reticular fibers, fibroblasts (reticular cells), macrophages, fat cells, and immature blood cells in all stages of maturation. New blood cells enter the blood through the sinusoid walls.

Cell Lines in Blood Cell Formation (pp. 547–549)

19. All blood cells continuously arise from blood stem cells. As these cells divide, there is an early separation into lymphoid stem cells (future lymphocytes) and myeloid stem cells (precursors to all

other blood cell classes). These stem cells commit to the specific blood cell lines and structural differentiation begins.

20. Erythrocytes start as proerythroblasts and proceed through various stages, during which hemoglobin accumulates and the organelles and nucleus are extruded. For their first 1 or 2 days in the circulation, erythrocytes are reticulocytes.
21. The three distinct classes of granular leukocytes begin as myeloblasts, then proceed through various stages in which they gain specific granules and their nucleus shuts down, distorting into a horseshoe shape. The cells then mature and enter the bloodstream. Some neutrophils enter the circulation as immature band cells.
22. Monocytes and lymphocytes look somewhat like stem cells. Structural changes are minimal in the developmental pathways of these cells.
23. In the platelet line, immature megakaryoblasts become giant megakaryocytes with multilobed nuclei. The cytoplasm of megakaryocytes breaks up to form platelets in the blood.

Disorders of the Blood (pp. 549–550)

24. Polycythemia is an excess of erythrocytes in the blood, and anemia is any condition in which the blood's capacity for carrying oxygen is diminished. Sickle cell disease is an inherited condition in which the erythrocytes distort into a sickle shape and block the capillaries. Leukemia is cancer of leukocyte-forming cells in bone marrow, and thrombocytopenia is abnormally low concentration of platelets in the blood.

The Blood Throughout Life (pp. 550–552)

25. The blood stem cells develop in blood islands of the yolk sac in the 3-week-old embryo and then travel to the hematopoietic organs.
26. The hematopoietic organs in the fetus are the liver, spleen, and bone marrow.
27. The incidence of leukemia, anemia, and clotting disorders increases with age.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Which of the following descriptions of erythrocytes is *false*? Erythrocytes (a) are shaped like biconcave discs, (b) have a life span of about 120 days, (c) contain hemoglobin, (d) have lobed nuclei.
2. Rank the following leukocytes in order of their relative abundance in the blood of a normal, healthy person, from 1 (most abundant) to 5 (least abundant).
 ____ (a) lymphocytes
 ____ (b) basophils
 ____ (c) neutrophils
 ____ (d) eosinophils
 ____ (e) monocytes
3. The white blood cell that releases histamine and other mediators of inflammation is the (a) basophil, (b) neutrophil, (c) monocyte, (d) eosinophil.

4. Which of the following blood cells are phagocytic? (a) lymphocytes, (b) erythrocytes, (c) neutrophils, (d) lymphocytes and neutrophils.
5. The blood cell that can attack a specific antigen is (a) a lymphocyte, (b) a monocyte, (c) a neutrophil, (d) a basophil, (e) an erythrocyte.
6. Match the names of the blood cells in column B with their descriptions in column A. Some names are used more than once.

Column A

- ____ (1) destroys parasites
- ____ (2) has two types of granules
- ____ (3) does not use diapedesis
- ____ (4) stops the allergic response
- ____ (5) the only cell that is not spherical
- ____ (6) granulocyte that phagocytizes bacteria
- ____ (7) the largest blood cell

Column B

- (a) erythrocyte
- (b) neutrophil
- (c) eosinophil
- (d) basophil
- (e) lymphocyte
- (f) monocyte

- (8) granulocyte with the smallest granules
 - (9) a young one is a reticulocyte
 - (10) lives for about 4 months
 - (11) most abundant blood cell
 - (12) includes T cells and B cells
7. In typically stained monocytes, the blue cytoplasm and the purple nuclei are colored by this dye: (a) eosin, (b) brilliant cresyl blue, (c) basin (as in basophilic), (d) methylene blue, (e) none of the above—you need two dyes for two colors.

Short Answer Essay Questions

8. Which class or classes of formed elements form the buffy coat in a centrifuged blood sample?
9. (a) What is the basic functional difference between red bone marrow and yellow bone marrow? (b) Where is yellow marrow located?
10. (a) Describe the steps of erythrocyte formation in the bone marrow. (b) What name is given to the immature type of red blood cell that is newly released into the circulation?
11. Describe the structure of platelets, and explain their functions.
12. What is the difference between a blood stem cell and a committed cell in the bone marrow?

13. What is the relationship between megakaryocytes and platelets?
14. Looking at a blood smear under the microscope, Tina became confused by the unusual nuclei of granulocytes. She kept asking why each eosinophil had two nuclei and why neutrophils had four or five nuclei. How would you answer her?
15. Compare and contrast each of the following pairs of terms: (a) circulatory system and cardiovascular system, (b) complete blood count and complete blood count with differential.
16. On her test, Floris wrote that the function of platelets was “clotting.” The instructor, however, demanded a more complete answer. Indicate what the instructor had in mind.
17. When leukocytes are examined in a blood count, is it possible to tell B lymphocytes from T lymphocytes? Explain your answer.
18. Compare an eosinophil to a basophil, both in structure and in function.
19. What are the advantages of placental-blood transplants over bone marrow transplants?
20. What are the functions of the following plasma proteins: globulins, albumin, fibrinogen?
21. How does serum differ from plasma?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. After young Janie was diagnosed as having acute lymphocytic leukemia, her parents could not understand why infection was a major problem for Janie when her WBC count was so high. Provide an explanation for Janie’s parents.
2. Freddy could tell that a neuron cell body on his slide was as wide as ten erythrocytes. How wide was the neuron cell body (in micrometers)?
3. The Jones family, who raise sheep on their ranch, let their sheep-dog Rooter lick their faces, and they would sometimes kiss him on the mouth. The same day that the veterinarian diagnosed Rooter as having tapeworms, a blood test indicated that both the family’s daughters had blood eosinophil levels of over 3000 per cubic millimeter. What is the connection?
4. A reticulocyte count indicated that 5% of Tyler’s red blood cells were reticulocytes. His blood test also indicated he had polycythemia and a hematocrit of 65%. Explain the connections among these three facts.
5. Cancer patients being treated with chemotherapy drugs, which are designed to destroy rapidly mitotic cells, are monitored closely for changes in their RBC and WBC counts. Why?
6. Your child has had a moderate fever for 2 days. On the third day, you take her to the pediatrician. After an examination, blood is drawn and a CBC with diff is performed. How does this information aid the pediatrician in determining whether the cause of the infection is viral or bacterial?



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The Heart 19

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Healthy cardiac muscle (colored TEM, longitudinal section).

RELATED CLINICAL TERMS

ASYSTOLE (a-sis'to-le; a = without) Failure of the heart to contract.

CARDIAC CATHETERIZATION Diagnostic procedure in which a fine catheter (tube) is passed from a blood vessel at the body surface to the heart. Blood-oxygen content, blood pressure, and blood flow are measured, and heart structures can be visualized. Findings help detect problems with the heart valves, heart deformities, and other cardiac malfunctions.

CARDIOMYOPATHY (kar'de-o-mi-op'ah-the) Any disease of the myocardium that weakens the heart's ability to pump.

ECHOCARDIOGRAPHY (ek'o-kar'de-og'rah-fe) Ultrasound imaging of the heart; used not only for imaging but also for measuring blood flow through the heart.

ENDOCARDITIS (en'do-kar-di'tis) Inflammation of the endocardium, usually confined to the endocardium of the heart valves. Endocarditis often results from infection by bacteria that have entered the bloodstream, but may result from fungal infections or an autoimmune response. Drug addicts may develop endocarditis by injecting themselves with contaminated needles. Additionally, the

bacteria can enter during routine dentistry and ear-piercing procedures.

HYPERTROPHIC CARDIOMYOPATHY Inherited condition in which the wall of the left ventricle (especially the interventricular septum) is abnormally thick and composed of disorganized muscle cells. Affects 1 of every 500 people. Because the lumen of the left ventricle is too small to hold all the atrial blood returning to it, blood pressure in the pulmonary circuit is elevated. Additionally, the grossly thickened myocardium becomes ischemic because it cannot get enough oxygen from the coronary vessels that supply it. Exercising can lead to fainting, chest pain, or even sudden death.

MYOCARDITIS (mi'o-kar-di'tis) Inflammation of the heart's myocardium. Sometimes follows an untreated streptococcal infection in children; may be extremely serious because it can weaken the heart and impair its ability to pump blood.

PERCUSSION Tapping the thorax or abdomen wall with the fingertips and using the nature of the resulting sounds to estimate the location, density, and size of the underlying organs. Percussion of the thoracic wall can be used to estimate the size of a patient's heart.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 19.

PAL = Practice Anatomy Lab™

1. The heart is a double pump whose right side pumps blood to the lungs for oxygenation and whose left side pumps blood throughout the body to nourish body tissues; that is, the right side is the pump of the pulmonary circuit, and the left side is the pump of the systemic circuit.
2. The four chambers of the heart are right and left atria (receiving chambers) and right and left ventricles (main pumping chambers).

Location and Orientation Within the Thorax (pp. 556–558)

3. The cone-shaped human heart, about the size of a fist, lies obliquely within the mediastinum. Its apex points anteriorly and to the left. Its base is its posterior surface.
4. From an anterior view, the heart is said to have four corners. The locations of its four corner points are described on p. 556.

Structure of the Heart (pp. 558–563)

Coverings (p. 558)

5. The pericardium encloses the heart. It consists of a superficial layer (fibrous pericardium and parietal layer of the serous pericardium), and a deeper layer that covers the heart surface (visceral layer of the serous pericardium, or epicardium). The pericardial cavity, between the two layers, contains lubricating serous fluid.

Layers of the Heart Wall (pp. 558–559)

6. The layers of the heart wall, from external to internal, are the epicardium, the myocardium (which consists of cardiac muscle tissue), and the endocardium (endothelium and connective tissue).

Heart Chambers (pp. 559–563)

7. On the external surface of the heart, several sulci separate the four heart chambers: the coronary sulcus and the anterior and posterior interventricular sulci. Internally, the right and left sides of the heart are separated by the interatrial and interventricular septa.
8. The right atrium has the following features: right auricle and pectinate muscles anteriorly; a smooth-walled posterior part; crista terminalis; openings of the coronary sinus and the superior and inferior venae cavae; SA and AV nodes; and fossa ovalis.
9. The right ventricle contains the following features: trabeculae carneae, papillary muscles, chordae tendineae, and right atrioventricular (tricuspid) valve. The pulmonary valve lies at the base of the pulmonary trunk.
10. The left atrium has a large, smooth-walled, posterior region into which open the four pulmonary veins. Anteriorly, its auricle is lined by pectinate muscles.
11. The left ventricle, like the right ventricle, contains papillary muscles, chordae tendineae, trabeculae carneae, and an atrioventricular valve (mitral). The aortic valve lies at the base of the aorta.

Heart Valves (pp. 563–576)

Valve Structure (p. 563)

12. The four heart valves are the atrioventricular valves (tricuspid and mitral) and the semilunar valves (aortic and pulmonary). All except the mitral have three cusps.
13. The fibrous skeleton of the heart surrounds the valves between the atria and ventricles. It anchors the valve cusps, is the point of insertion of the heart musculature, and blocks the direct spread of electrical impulses from the atria to the ventricles.

Valve Function (p. 563)

14. The atrioventricular valves prevent backflow of blood into the atria during contraction of the ventricles. The pulmonary and aortic semilunar valves prevent backflow into the ventricles during relaxation of the ventricles.

Heart Sounds (pp. 563–565)

15. Using a stethoscope, physicians can listen to the sounds produced by the closing atrioventricular and semilunar valves. Each valve is best heard near a different heart corner on the anterior chest wall (see Figure 19.9).

Pathway of Blood Through the Heart (pp. 566–568)

16. A drop of blood circulates along the following path: right atrium to right ventricle to pulmonary circuit to left atrium to left ventricle to systemic circuit to right atrium.
17. In each heartbeat, both atria contract together, followed by simultaneous contraction of both ventricles.
18. The wall of the left ventricle is thicker than that of the right ventricle, resulting in higher pressure in the systemic circuit.

Cardiac Muscle Tissue (pp. 568–569)

19. Cardiac muscle tissue forms the thick myocardium of the heart wall. It contains cardiac muscle cells and connective tissues that surround these cells.
20. Cardiac muscle cells are short, branching, striated cells with one or two central nuclei. They contain myofibrils made of typical sarcomeres. Cardiac muscle contracts by the sliding filament mechanism.
21. Adjacent cardiac cells are connected by intercalated discs to form cardiac fibers. Intercalated discs contain two types of junctions: desmosome-like fascia adherens and gap junctions. Gap junctions between cells allow the direct transmission of an electrical impulse through the entire network of cardiac muscle cells.
22. Cardiac muscle cells have many mitochondria and depend on aerobic respiration to form ATP. They are very resistant to fatigue.
23. Contraction of cardiac muscle is triggered by Ca^{2+} . Some of this calcium comes from the extracellular fluid. The sarcoplasmic reticulum and T tubules are somewhat simpler than those of skeletal muscle.
24. Cardiac muscle cells contract with their own inherent rhythm, the basis of the heartbeat.

PAL Human Cadaver/Cardiovascular System/Heart

Conducting System and Innervation (pp. 570–572)**Conducting System (pp. 570–571)**

25. The conducting system of the heart is an interconnected series of specialized cardiac muscle cells that initiates each heartbeat, sets the basic rate of the heartbeat, and coordinates the contraction of the heart chambers. The impulse that signals heart contraction travels from the SA node (the pacemaker) through the atrial myocardium and internodal pathway to the AV node, to the atrioventricular bundle, bundle branches, Purkinje fibers, and the ventricular musculature.

Innervation (pp. 571–572)

26. Heart innervation consists of visceral sensory fibers, heart-slowing vagal parasympathetic fibers, and sympathetic fibers that increase heart rate and force of contraction.

Blood Supply to the Heart (p. 572)

27. The coronary vessels that supply the heart wall are located in the coronary sulcus and interventricular sulci. The right and left coronary arteries branch from the base of the aorta to supply the heart wall. Venous blood, collected by the cardiac veins (great, middle, small, and anterior), empties into the coronary sinus, which opens into the right atrium.

Disorders of the Heart (pp. 572–574)

28. Coronary artery disease is caused by atherosclerotic blockage of the coronary arteries, and can lead to angina pectoris and myocardial infarction (heart attack). Heart failure is a weakening of the heart, resulting in its inability to pump blood fast enough to meet the body's needs. Atrial and ventricular fibrillations are rapid, irregular, and uncoordinated contractions of the respective heart chambers, resulting from damage to the conducting system.

The Heart Throughout Life (pp. 573–576)**Development of the Heart (pp. 573–576)**

29. The heart develops from splanchnic mesoderm around the head and neck of the embryonic disc. When the heart folds into the thorax, it is a double tube that soon fuses into one and starts pumping blood (day 22). It soon bends into an S shape. Its four earliest chambers are the sinus venosus, atrium, ventricle, and bulbus cordis.
30. The four final heart chambers are defined during month 2 through the formation of valves and dividing walls. Failures in this complex process account for most congenital defects of the heart (see Figure 19.18).

The Heart in Adulthood and Old Age (p. 576)

31. Age-related changes in the heart include hardening and thickening of the valve cusps, decline in cardiac reserve, fibrosis of cardiac muscle, and atherosclerosis.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. The most external part of the pericardium is the (a) parietal layer of serous pericardium, (b) fibrous pericardium, (c) visceral layer of serous pericardium, (d) pericardial cavity.
2. Which heart chamber forms most of the heart's inferior surface? (a) right atrium, (b) right ventricle, (c) left atrium, (d) left ventricle.
3. How many cusps does the right atrioventricular valve have? (a) two, (b) three, (c) four.

4. The sequence of contraction of the heart chambers is (a) random, (b) left chambers followed by right chambers, (c) both atria followed by both ventricles, (d) right atrium, right ventricle, left atrium, left ventricle.
5. The middle cardiac vein runs with which artery? (a) marginal artery, (b) aorta, (c) coronary sinus, (d) anterior interventricular artery, (e) posterior interventricular artery.
6. The base of the heart (a) is its posterior surface, (b) lies on the diaphragm, (c) is the same as its apex, (d) is its superior border.

7. Which of the following is an *incorrect* statement about the crista terminalis of the right atrium? (a) It separates the smooth-walled part from the part with pectinate muscles. (b) It is shaped like the letter C. (c) The coronary sinus and inferior vena cava open near its inferior part. (d) It lies mostly in the interatrial septum.
8. The aortic valve closes (a) at the same time the mitral valve closes, (b) just after the atria contract, (c) just before the ventricles contract, (d) just after the ventricles contract.
9. The ventricle of the embryonic heart gives rise to what adult structure(s)? (a) bulbus cordis, (b) both ventricles, (c) left ventricle, (d) the aorta, (e) none of these.
10. Which layer of the heart wall is the thickest? (a) endocardium, (b) myocardium, (c) epicardium, (d) endothelium.
11. The inferior left corner of the heart is located at the (a) second rib slightly lateral to the sternum, (b) third rib at the sternum, (c) sixth rib slightly lateral to the sternum, (d) fifth intercostal space at the midclavicular line.
12. Ben was annoyed when the teaching assistant who ran the discussion section of his anatomy class said that the atria pump blood to the lungs, and the ventricles pump blood throughout the body. Correct this error.
13. Describe the location of the heart within the thorax.
14. Trace a drop of blood through all the heart chambers and heart valves, and through the basic vascular circuits, from the time it enters the left atrium until it returns to the left atrium again.
15. (a) Name the elements of the heart's conducting system in order, beginning with the pacemaker. (b) Is the conducting system made of nerves? Explain. (c) What are the functions of this conducting system?
16. Sketch the heart and draw all the coronary vessels in their correct locations. (Alternatively, you could locate these vessels on a realistic diagram of the heart.)
17. On a diagram of a frontally sectioned heart, indicate the location of the fibrous skeleton.
18. When you view a heart's *anterior* surface, which of its four chambers appears largest?
19. Make a drawing of the adult heart and the associated large vessels. Then color and label the adult regions that derive from each *embryonic* heart chamber: (a) sinus venosus, (b) embryonic atrium, (c) embryonic ventricle, (d) bulbus cordis.
20. How do the right and left ventricles differ structurally, and how do these structural differences reflect functional differences?
21. Which is more resistant to fatigue, cardiac muscle or skeletal muscle? What is the anatomical basis for this difference, and why is it important?
22. Describe the structure and function of an intercalated disc.
23. Compare and contrast the structure of cardiac muscle tissue with skeletal muscle tissue.

Short Answer Essay Questions

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. After studying Figure 19.17, classify the three congenital heart defects depicted according to whether they produce (1) mixing of oxygenated and unoxygenated blood, (2) increased workload for the ventricles, or (3) both of these problems.
2. Ms. Hamad, who is 73 years old, is admitted to the coronary care unit of a hospital with a diagnosis of left ventricular failure resulting from a myocardial infarction. Her heart rhythm is abnormal. Explain what a myocardial infarction is, how it is likely to have been caused, and why the heart rhythm is affected.
3. You have been called on to demonstrate where to listen for heart sounds. Explain where on the chest wall you would place a stethoscope to listen for (a) incompetence of the aortic valve and (b) stenosis of the mitral valve.
4. After a man was stabbed in the chest, his face became blue and he lost consciousness from lack of oxygenated blood to the brain. The diagnosis was cardiac tamponade rather than severe blood loss through internal bleeding. What is cardiac tamponade, how did it cause the observed symptoms, and how is it treated?
5. A heroin addict felt tired, weak, and feverish, with vague pains and aches. Finally, he went to a doctor, terrified that he had AIDS. Instead, the doctor found an abnormal heart sound, and the final diagnosis was not AIDS but endocarditis. What is the most likely way that this patient contracted endocarditis?
6. Another patient had an abnormal heart sound that indicated a stenotic valve. Define this condition, and contrast it with an incompetent heart valve.
7. Assume that the four corner points of a patient's heart, as revealed on an X-ray film, relate to the rib cage as follows: second right rib at sternum, tip of xiphoid process, seventh intercostal space lateral to the left nipple, and second left rib at sternum. Are the size and position of this patient's heart normal?
8. During a lethal heart attack, a blood clot lodges in the first part of the circumflex branch of the left coronary artery, blocking blood flow through this vessel. What regions of the heart will become ischemic and die?
9. Blood from the ventricles is "squeezed" out of the heart from the apex toward the great arteries. What features of the heart contribute to this sequence of contraction?



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affect women more), but others are preventable. Many people wrongly believe that women do not get atherosclerosis, so some women may not recognize the symptoms of angina or a heart attack in time to seek help.

check your understanding

12. What lifestyle factors contribute to the development of atherosclerosis?

13. How does elevated blood glucose associated with diabetes mellitus affect the delivery of oxygen and nutrients to body tissues?
14. Which vessel in the fetus carries the most highly oxygenated blood?
15. Where is the ductus arteriosus located, and how does it function to shunt blood from the pulmonary circuit?

For answers, see Appendix B.

RELATED CLINICAL TERMS

ANGIOGRAPHY (an-jē-og'ra-fē; *angio* = vessel; *graphy* = writing) Diagnostic technique involving the infusion of a radiopaque substance into the bloodstream for X-ray examination of specific blood vessels. Angiography is the major way of diagnosing occlusion of coronary arteries and risk of heart attack. The images obtained with this procedure are called *angiograms*.

ANGIOSARCOMA Cancer originating from the endothelium of a blood vessel; may develop in liver vessels following exposure to chemical carcinogens.

BLUE BABY A baby with cyanosis (skin appears blue) due to relatively low levels of oxygen in the blood. This condition is caused by any congenital defect that leads to low oxygenation of the systemic blood, including patent (open) foramen ovale and patent ductus

arteriosus (see above), failure of the lungs to inflate at birth, and other conditions (see p. 576).

CAROTID ENDARTERECTOMY Surgical procedure for scraping away atherosclerotic plaques that block the base of the internal carotid artery; done to decrease the risk of a stroke.

PHLEBITIS (fle-bi'tis; *phleb* = vein; *itis* = inflammation) Inflammation of a vein, accompanied by painful throbbing and redness of the skin over the inflamed vein; most often caused by bacterial infection or local physical trauma.

PHLEBOTOMY (fle-bot'o-me; *tomy* = cut) An incision made in a vein for withdrawing blood.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 20.

PAL = Practice Anatomy Lab™

PART 1: GENERAL CHARACTERISTICS OF BLOOD VESSELS (pp. 581–588)

1. The main types of blood vessels are arteries, capillaries, and veins. Arteries carry blood away from the heart and toward the capillaries; veins carry blood away from the capillaries and toward the heart. Arteries “branch,” whereas veins “serve as tributaries.”

Structure of Blood Vessel Walls (p. 581)

2. All but the smallest blood vessels have three tunics: tunica intima (with an endothelium), tunica media (mostly smooth muscle), and tunica externa (external connective tissue). The tunica media, which changes the diameter and strengthens the wall of the vessel, is thicker in arteries than in other types of blood vessels.

Types of Blood Vessels (pp. 581–588)

3. The three classes of arteries, from large to small, are elastic arteries, muscular arteries, and arterioles. Elastic (conducting) arteries, the largest arteries near the heart, contain more elastin than does any other vessel type. The elastin in all arteries helps dampen the pressure pulses produced by the heartbeat.
4. Muscular (distributing) arteries carry blood to specific organs and organ regions. These arteries have a thick tunica media bordered by elastic lamina and are most active in vasoconstriction.
5. Arterioles, the smallest arteries, have one or two layers of smooth muscle cells in their tunica media. They regulate the flow of blood into capillary beds.

6. Capillaries, which have diameters slightly larger than erythrocytes, are endothelium-walled tubes arranged in networks called capillary beds. The most permeable capillaries have fenestrations (pores) in their endothelial cells; other capillaries are continuous (lack pores). Spider-shaped pericytes help support the capillary wall.
7. Sometimes, blood is shunted straight through a capillary bed (from arteriole to metarteriole to thoroughfare channel to venule) and does not enter the true capillaries to the surrounding tissue. Precapillary sphincters determine how much blood enters the true capillaries.
8. The four routes involved in capillary permeability are (1) through intercellular clefts between endothelial cells, (2) through the pores of fenestrated capillaries, (3) by direct diffusion of respiratory gases across the endothelium, and (4) through endothelial pinocytotic vesicles.
9. Sinusoids are wide, twisted, leaky capillaries.
10. The smallest veins, postcapillary venules, function like capillaries.
11. Because venous blood is under less pressure than arterial blood, the walls of veins are thinner than those of arteries of comparable size. Veins also have a wider lumen, a thinner tunica media, and a thicker tunica externa.
12. Many veins have valves that prevent the backflow of blood. The skeletal muscle pump aids to move blood through veins. Varicose veins are veins whose valves have failed.

Vascular Anastomoses (p. 588)

13. The joining together of arteries serving a common organ, called an arterial anastomosis, provides collateral channels for blood to

reach the same organ. Anastomoses between veins are more common than anastomoses between arteries.

Vasa Vasorum (p. 588)

14. Vasa vasorum are small arteries, capillaries, and veins that supply the outer part of the wall of larger blood vessels.

PART 2: BLOOD VESSELS OF THE BODY (pp. 589–614)

The Pulmonary Circulation (pp. 589–591)

15. The pulmonary trunk splits inferior to the aortic arch into the right and left pulmonary arteries. These arteries divide into lobar arteries, then branch repeatedly in the lung. Arising from the capillary beds, pulmonary venous tributaries empty newly oxygenated blood into the superior and inferior pulmonary veins of each lung. The four pulmonary veins extend from the lungs to the left atrium.

The Systemic Circulation (pp. 591–608)

16. Figures 20.8 and 20.16 summarize the main arteries and veins of the systemic circulation. The systemic circuit begins with the aorta (ascending aorta, aortic arch, descending aorta) and ends with the two large venae cavae and the coronary sinus.

PAL Human Cadaver/Cardiovascular System/Arteries, and Human Cadaver/Cardiovascular System/Veins

17. A portal system is a set of vessels in which *two* capillary beds, interconnected by a vein, lie between the initial artery and final vein. The hepatic portal system is a special subcirculation that drains the digestive organs of the abdomen and pelvis (see Figure 20.21).
18. Cirrhosis of the liver leads to portal hypertension, in which blood backs up through the portal-systemic anastomoses, overloading these delicate veins. This overload leads to esophageal bleeding, hemorrhoids, and caput medusae.

Disorders of the Blood Vessels (pp. 609–611)

19. *Atherosclerosis*, the most important vascular disorder, is discussed in A Closer Look on p. 610. *Deep vein thrombosis of the lower limb* is the formation of clots in veins of the lower extremity. In *venous disease*, the failure of venous valves in some lower-limb veins results in inadequate drainage of venous blood from the limb, whose tissues consequently become ischemic and vulnerable to ulceration. An *aneurysm* is a widening or outpocketing of an artery (or vein). In *microangiopathy of diabetes*, the capillaries are leaky because of sugar deposits in their basement membrane. In *arteriovenous malformation*, the capillaries fail to develop between some important artery and the vein that drains it, often leading to a rupture or an aneurysm of the vein.

Blood Vessels Throughout Life (pp. 611–614)

20. The first blood vessels develop from blood islands on the yolk sac in the 3-week embryo. Soon, vessels begin forming from mesoderm inside the embryo. The formation of new vessels, whether in the embryo or adult, occurs mainly through the sprouting of endothelial buds from existing vessels.
21. The pattern of blood vessels is the same in both the fetus and the newborn, and blood flows through these vessels in the same directions. However, the fetus also has vessels to and from the placenta (umbilical arteries, umbilical vein, and ductus venosus) and two shunts that bypass the nearly nonfunctional pulmonary circuit (the foramen ovale in the interatrial septum, and the ductus arteriosus between the pulmonary trunk and aortic arch). Fetal shunts and vessels close shortly after birth.
22. The most important age-related vascular disorder is the progression of atherosclerosis.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Which of the following statements does *not* correctly describe veins? (a) They have less elastic tissue and smooth muscle than arteries. (b) They are subject to lower blood pressures than arteries. (c) They have larger lumens than arteries. (d) They always carry deoxygenated blood.
- In atherosclerosis, which of the following layers of the artery wall thickens most? (a) tunica media, (b) tunica intima, (c) tunica externa.
- Blood flow through the capillaries is steady despite the rhythmic pumping action of the heart because of the (a) elasticity of the large arteries only, (b) elasticity of all the arteries, (c) ligamentum arteriosum, (d) venous valves.
- Fill in the blanks with the name of the appropriate vascular tunic (intima, media, or externa).
 - (1) contains endothelium
 - (2) the tunic with the largest vasa vasorum
 - (3) the thickest tunic in veins
 - (4) the outer tunic; is mostly connective tissue
 - (5) is mostly smooth muscle
 - (6) forms the valves of veins
- Which of the following vessels is bilaterally symmetrical (that is, has an identical member of a pair on either side of the body)? (a) internal carotid artery, (b) brachiocephalic trunk, (c) azygos vein, (d) superior mesenteric vein.
- Identify which artery is *missing* from the following sequence, which traces the flow of arterial blood to the right hand: Blood leaves the heart and passes through the aorta, the right subclavian artery, the axillary and brachial arteries, and through either the radial or ulnar artery to a palmar arch. (a) left coronary, (b) brachiocephalic, (c) cephalic, (d) right common carotid.
- Which of the following veins do not drain directly into the inferior vena cava? (a) lumbar veins, (b) hepatic veins, (c) inferior mesenteric vein, (d) renal veins.
- A stroke that blocks a posterior cerebral artery will most likely affect (a) hearing, (b) sight, (c) smell, (d) higher thought processes.
- Tell which artery is *missing* from the following sequence, which traces the flow of arterial blood to the left parietal and temporal lobes of the brain: Blood leaves the heart and passes through the aorta, the left common carotid artery, and the middle cerebral artery. (a) vertebral, (b) brachiocephalic, (c) internal carotid, (d) basilar.
- Tell which two veins are *missing* from the following sequence: Tracing the drainage of *superficial* venous blood from the leg, blood enters the great saphenous vein, femoral vein, inferior vena cava, and right atrium. (a) coronary sinus and superior vena cava,

- (b) posterior tibial and popliteal, (c) fibular (peroneal) and popliteal, (d) external and common iliacs.
11. The inferior mesenteric artery supplies the (a) rectum and part of the colon, (b) liver, (c) small intestine, (d) spleen.
 12. Tell which two vessels are *missing* from the following sequence: Tracing the drainage of venous blood from the small intestine, blood enters the superior mesenteric vein, hepatic vein, inferior vena cava, and right atrium. (a) coronary sinus and left atrium, (b) celiac and common hepatic veins, (c) internal and common iliac veins, (d) hepatic portal vein and liver sinusoids.
 13. Tell which vessel is *missing* from the following vascular circuit: Tracing the circulation to and from the placenta, a drop of blood travels in the fetus from the left ventricle to the aorta, to a common iliac artery, to an internal iliac artery, to an umbilical artery, to capillaries in the placenta, to the ductus venosus, to a hepatic vein, to the inferior vena cava, to the right atrium, to the foramen ovale, to the left atrium, and to the left ventricle. (a) umbilical vein, (b) ligamentum arteriosum, (c) internal carotid artery, (d) capillaries in the small intestine.
 14. A pressure point is a place where one presses on an artery through the body surface to stop bleeding more distally. Which of the following sites is not a pressure point for any major artery? (a) the medial bicipital furrow on arm, (b) the sciatic artery in middle of gluteus maximus, (c) the midinguinal point in the femoral triangle.
 15. Which of the following is not a pulse point? (a) anatomical snuff box, (b) inferior margin of mandible anterior to masseter muscle, (c) center of distal forearm at palmaris longus tendon, (d) medial bicipital furrow on arm, (e) dorsum of foot between the first two metatarsals.
 16. A nurse missed a patient's median cubital vein while trying to draw blood and then inserted the needle far too deeply into the

cubital fossa. This error could cause any of the following problems *except* (a) paralysis of the ulnar nerve, (b) paralysis of the median nerve, (c) bruising the insertion tendon of the biceps brachii muscle, (d) blood spurting from the brachial artery.

Short Answer Essay Questions

17. (a) What structural features are responsible for the permeability of capillary walls? (b) Which of these features are absent from brain capillaries in the blood-brain barrier?
18. Distinguish among elastic arteries, muscular arteries, and arterioles relative to their location, histology, and functions.
19. (a) Name an organ containing fenestrated capillaries. (b) What is a sinusoid?
20. Sketch the arterial circle at the base of the brain, and label the important arteries that branch off this circle.
21. (a) What are the two large tributaries that form the hepatic portal vein? (b) What is the function of the hepatic portal circulation?
22. State the location and basic body regions drained by the azygos vein.
23. Name all four pulmonary veins.
24. What are the ductus venosus and ductus arteriosus, where are they located, what are their functions, and how are they different?
25. Differentiate between arteriosclerosis and atherosclerosis.
26. Figure 20.8b shows where to feel the pulses of various arteries. Name the artery from which each artery listed in the figure branches. Here is an example to get you started: The superficial temporal artery *is a branch of the external carotid artery*.

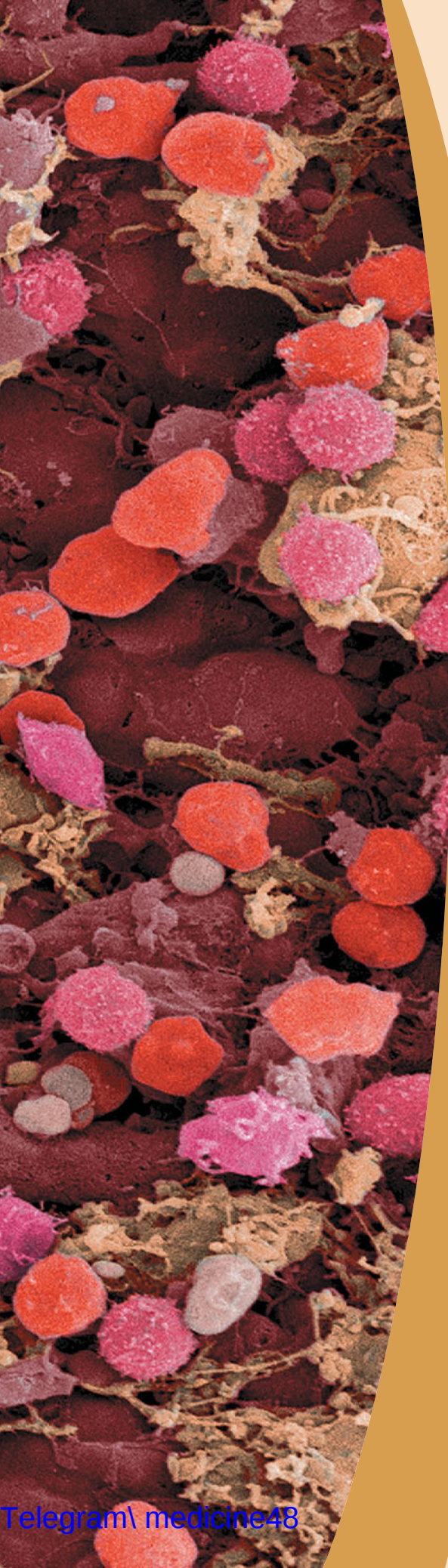
CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. In an eighth-grade health class, the teacher warned the students not to squeeze pimples or pluck hairs on their nose and upper lip. The students made fun of this warning, but they got the message when the teacher explained the danger triangle of the face. What is the danger of infections in this area?
2. Logically deduce which is the more difficult and dangerous surgery on a child: closing a patent ductus arteriosus or closing a patent foramen ovale. Explain your reasoning.
3. Samantha accidentally received a small but deep puncture wound from broken glass in the exact midline of the anterior side of her distal forearm. She worried during the 10-minute drive to the hospital that she would bleed to death because she had heard stories about people dying from slashing their wrist. Look at Figure 20.11, and determine whether her fear of bleeding to death is justified. Explain your reasoning.
4. Your friend, who knows little about science, is reading a magazine article about a patient who had an "aneurysm at the base of his brain that suddenly grew much larger." The surgeons' first goal was to "keep it from rupturing," and their second goal was to "relieve the pressure on the brain stem and cranial nerves." The surgeons were able to "replace the aneurysm with a section of plastic tubing," and the patient recovered. Your friend asks you what all this means. Explain. (Start by checking the section on blood vessel disorders.)
5. Describe some consequences of the loss of elasticity in the conducting arteries, as occurs in arteriosclerosis ("hardening of the arteries").
6. In coronary bypass surgery, the internal thoracic artery can be used as the bypass vessel by suturing its distal end onto the obstructed coronary artery in the heart wall. Explain why using this vessel is superior to using the great saphenous vein of the leg.
7. Occasionally, either the ductus arteriosus or the foramen ovale stays patent (open) after birth. What functional deficit do both these conditions produce?
8. (a) Explain in your own words why varicose veins are more common in the lower limbs than elsewhere in the body. (b) Give a functional reason why valves are more abundant in veins of the upper and lower limbs than in veins of the neck.



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Segmentation By \ Belal Shams AlDin



The Lymphatic and Immune Systems

21

The Lymphatic System 618

- Lymphatic Capillaries 619
- Lymphatic Collecting Vessels 619
- Lymph Nodes 619
- Lymph Trunks 620
- Lymph Ducts 621

The Immune System 622

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Disorders of the Lymphatic and Immune Systems 631

The Lymphatic and Immune Systems Throughout Life 631

After considering the cardiovascular system in the previous three chapters, we now turn to the closely related lymphatic and immune systems. The main function of the **lymphatic system** is to return excess tissue fluid back to the blood vascular system. The *lymphatic vessels* collect this fluid and transport it to the bloodstream. The **immune system** protects our bodies from foreign organisms by fighting infections and conferring immunity to disease. The main components of the immune system are *lymphocytes*, *lymphoid tissue*, and *lymphoid organs* (such as the spleen, lymph nodes, and thymus).



Freeze fracture section through the medullary sinus of a lymph node; dark red reticular cells are in the background (colored SEM).

RELATED CLINICAL TERMS

KAPOSI'S SARCOMA Tumorlike lesions of the skin and some internal organs, seen in some AIDS patients. The lesions are vascularized and arise from proliferating capillary endothelial cells. The capillaries are so permeable that they leak erythrocytes, giving the lesions a purple color. Kaposi's sarcoma is now known to be caused by a previously unrecognized type of herpes virus that infects the endothelium. Confusion exists as to whether the lesions are merely due to cellular hyperplasia or are true tumors. Treatment is with chemotherapy.

LYMPHADENOPATHY (lim-fad'ē-nop-ah-the) (*adeno* = gland; *pathy* = disease) Any disease of the lymph nodes.

LYMPHOMA Any neoplasm (tumor) of the lymphoid tissue, whether benign or malignant.

SENTINEL LYMPH NODE IN CANCER The first node that receives lymph draining from a body area suspected of having a tumor. When

examined for the presence of cancer cells, this node gives the best indication of whether metastasis (spread) through the lymph vessels has occurred.

SPLENOMEGALY (sple"no-meg'ah-le; "spleen big") Enlargement of the spleen, usually resulting from blood diseases such as mononucleosis, malaria, leukemia, or polycythemia vera. A way that physicians diagnose spleen enlargement is by feeling for the spleen's notched superior border through the skin of the abdominal wall just anterior to the costal margin. A healthy spleen never reaches this far anteriorly.

TONSILLITIS Congestion of the tonsils, typically with infecting bacteria, which causes them to become red, swollen, and sore.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 21.

PAL = Practice Anatomy Lab™

1. The lymphatic system consists of lymphatic circulatory vessels that carry lymph. The immune system contains the lymphocytes, lymphoid tissue, and lymphoid organs, which are involved in the body's fight against disease.

The Lymphatic System (pp. 618–622)

2. Lymph is excess tissue fluid, which originates because slightly more fluid leaves blood capillaries than returns there. Lymphatic vessels pick up this excess fluid and return it to the great veins at the root of the neck.
3. Lymphatic vessels also retrieve blood proteins that leak from capillaries and return these proteins to the bloodstream.
4. The vessels of the lymphatic system, from smallest to largest, are lymphatic capillaries, lymphatic collecting vessels (with lymph nodes), lymph trunks, and lymph ducts.

Lymphatic Capillaries (p. 619)

5. Lymphatic capillaries weave through the loose connective tissues of the body. These closed-end tubes are highly permeable to entering tissue fluid and proteins because their endothelial cells are loosely joined. Disease-causing microorganisms and cancer cells also enter the permeable lymphatic capillaries and spread widely through the lymph vessels.
6. Lymphatic capillaries called lacteals absorb digested fat from the small intestine.

Lymphatic Collecting Vessels (p. 619)

7. Lymphatic collecting vessels run alongside arteries and veins but have thinner walls and many more valves than do veins. The collecting vessels resemble a string of beads.
8. Lymph flows very slowly through lymphatic collecting vessels. Flow is maintained by normal body movements, contractions of skeletal muscles, arterial pulsations, and contraction of smooth

muscle in the wall of the lymphatic vessel. Lymphatic valves prevent backflow.

Lymph Nodes (pp. 619–620)

9. Clustered along the lymphatic collecting vessels, bean-shaped lymph nodes remove infectious agents and cancer cells from the lymph stream. Lymph enters the node via afferent lymphatic vessels and exits via efferent vessels at the hilum. In between, the lymph percolates through lymph sinuses, where macrophages remove lymph-borne pathogens. For a diagram of the body's main groups of lymph nodes, see Figure 21.2.

Lymph Trunks (p. 620)

10. The lymph trunks (lumbar, intestinal, bronchomediastinal, subclavian, and jugular) each drain a large body region. All except the intestinal trunk are paired.

Lymph Ducts (pp. 621–622)

11. The right lymphatic duct (and/or the nearby trunks) drains lymph from the superior right quarter of the body. The thoracic duct (and/or the nearby trunks) drains lymph from the rest of the body. These two ducts empty into the junction of the internal jugular and subclavian veins. The thoracic duct starts at the cisterna chyli at L₁–L₂ and ascends along the thoracic vertebral bodies.

PAL Human Cadaver/Lymphatic System

The Immune System (pp. 622–630)

12. Lymphoid organs and lymphoid tissues house millions of lymphocytes, important cells of the immune system that recognize specific antigens.

Lymphocytes (pp. 623–624)

13. B and T lymphocytes fight infectious microorganisms in the loose and lymphoid connective tissues of the body—B cells by producing antibody-secreting plasma cells, and cytotoxic (CD8⁺) T cells by directly killing antigen-bearing cells. B cells and antibodies are best at destroying bacteria and bacterial products, whereas T cells are best at destroying eukaryotic cells that express surface antigens, such as virus-infected cells and grafted and tumor cells.

Natural killer lymphocytes do not recognize specific antigens but rapidly attack and kill tumor cells and virus-infected cells.

14. Mature lymphocytes patrol connective tissues throughout the body by passing in and out of the circulatory vessels (recirculation).

Lymphocyte Activation (pp. 624–625)

15. Lymphocytes arise from stem cells in the bone marrow. T cells develop immunocompetence in the thymus, whereas B cells develop immunocompetence in the bone marrow. Immunocompetent lymphocytes then circulate to the loose and lymphoid connective tissues, where antigen binding (the antigen challenge) leads to lymphocyte activation.
16. The antigen challenge involves an interaction among the lymphocyte being activated, an antigen-presenting cell (dendritic cell or macrophage), and a helper ($CD4^+$) T lymphocyte. A newly activated T or B cell divides quickly to produce many short-lived effector lymphocytes and some long-lived memory lymphocytes. Recirculating memory lymphocytes provide long-term immunity.

Lymphoid Tissue (pp. 625–627)

17. Lymphoid tissue is an often-infected reticular connective tissue in which many B and T lymphocytes gather to fight pathogens or become activated. It is located in the mucous membranes (as MALT) and in the lymphoid organs (except the thymus).
18. Lymphoid tissue contains lymphoid follicles (nodules) with germinal centers. Each follicle contains thousands of B lymphocytes, all derived from one activated B cell.

Lymphoid Organs (pp. 627–630)

19. The thymus, located in the superoanterior thorax and neck, is a primary lymphoid organ that is most active during youth. Its hormones, secreted by epithelial reticular cells, signal the contained T lymphocytes to gain immunocompetence.
20. The thymus has lobules, each with an outer cortex packed with maturing T cells and an inner medulla containing fewer T cells and degenerative thymic (Hassall's) corpuscles.

21. Within a lymph node, masses of lymphoid tissue lie between the sinuses. This lymphoid tissue receives some of the antigens that pass through the node, leading to lymphocyte activation and memory-lymphocyte production. The masses help divide each node into an outer cortex and an inner medulla.
22. The spleen lies in the superior left part of the abdominal cavity. The splenic vessels enter and exit the hilum on the anterior surface.
23. The spleen has two main functions: (1) removing antigens from the blood and (2) destroying worn-out blood cells. The first function is performed by the white pulp; the second, by the red pulp. White pulp consists of sleeves of lymphoid tissue, each surrounding a central artery. Red pulp consists of venous sinuses and strips of blood-filled reticular connective tissue called splenic cords, whose macrophages remove worn-out blood cells.
24. The tonsils in the pharynx, aggregated lymphoid nodules in the small intestine, and the wall of the appendix are parts of MALT in which the lymphoid tissue contains an exceptionally high concentration of lymphocytes and follicles.

Disorders of the Lymphatic and Immune Systems (p. 631)

25. Chylothorax is the leakage of chyle from the thoracic duct into the pleural cavity. Lymphangitis is inflammation of a lymphatic vessel. Mononucleosis is a viral infection of B lymphocytes, which are attacked by T lymphocytes, leading to flulike symptoms. Hodgkin's disease is a type of lymph node cancer, and non-Hodgkin's lymphoma includes all other cancers of lymphoid tissue.

The Lymphatic and Immune Systems Throughout Life (p. 631)

26. Lymphatic vessels develop from lymphatic sacs attached to the embryonic veins. The thymus develops from pharyngeal endoderm, and the other lymphoid organs derive from mesenchyme.
27. Lymphoid organs become populated by lymphocytes, which arise from hematopoietic tissue.
28. With aging, the immune system becomes less responsive. Thus, the elderly suffer more often from infections and cancer.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Lymphatic capillaries (a) are open-ended like drinking straws, (b) have continuous tight junctions like those of the capillaries of the blood-brain barrier, (c) have endothelial cells separated by flaplike minivalves that open wide, (d) have special barriers that stop cancer cells from entering, (e) all of the above.
2. The basic structural framework of most lymphoid organs consists of (a) areolar connective tissue, (b) hematopoietic tissue, (c) reticular connective tissue, (d) adipose tissue.
3. Lymph nodes cluster in all the following body areas except the (a) brain, (b) axillae, (c) groin, (d) neck.
4. The germinal centers in lymph nodes are sites of (a) the lymph sinuses, (b) proliferating B lymphocytes, (c) T lymphocytes, (d) a and c, (e) all of the above.
5. The red pulp of the spleen (a) contains venous sinuses and a macrophage-rich connective tissue, (b) is another name for the fibrous capsule, (c) is lymphoid tissue containing lymphocytes,

(d) is the part of the spleen that destroys worn-out erythrocytes, (e) a and d.

6. Lymphocytes that develop immunocompetence in the thymus are (a) B lymphocytes, (b) T lymphocytes.
7. Which of the following lymphoid organs have a cortex and a medulla? (More than one choice is correct.) (a) lymph nodes, (b) spleen, (c) thymus, (d) aggregated lymphoid nodules, (e) tonsils.
8. Which one of the following lymphoid organs does *not* contain lymphoid follicles or germinal centers? (a) lymph nodes, (b) spleen, (c) thymus, (d) aggregated lymphoid nodules, (e) tonsils.
9. Developmentally, the embryonic lymphatic vessels are most closely associated with the (a) veins, (b) arteries, (c) nerves, (d) thymus.
10. It sometimes is difficult to distinguish the different lymphoid organs from one another in histological sections. How would you tell the thymus from a lymph node? (a) Only the thymus has a cortex and medulla; (b) lymphocytes are far less densely packed in the thymus than in the lymph node; (c) the thymus contains no blood

vessels; (d) only the thymus has distinct lobules and thymic (Hassall's) corpuscles.

11. In some people, the thoracic duct does not receive any of the lymph trunks at the base of the neck (jugular, subclavian, or bronchomediastinal). In such people, what part of the body does the thoracic duct drain? (a) upper right quarter, (b) upper left quarter, (c) upper half, (d) lower half.

Short Answer Essay Questions

12. Compare the basic functions of a lymph node to those of the spleen.
13. If you saw a blood vessel and a lymphatic collecting vessel running side by side, how could you tell them apart?
14. Trace the entire course of the thoracic duct. Name the locations of all the lymph trunks.
15. List and briefly explain three important functions of the lymphatic vessels.
16. Which three of the six groups of lymph nodes described on p. 620 are easily felt (palpated) through the skin during a physical examination?
17. Explain the basic functional differences between B and T lymphocytes.
18. As George was reading this chapter for the second time, he suddenly had an insight, exclaiming, "Lymph comes from the blood, and then it returns to the blood!" Is this insight correct? Explain.
19. Billie Jo is looking at histological slides of the spleen under a microscope. She says that she sees lymphoid follicles in the white pulp. Is she correct? Explain.
20. Aparna, a gross anatomist who has been teaching human anatomy for 35 years, told her class that in adults the thymus is atrophied and has no function. Is she correct? Explain.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. A friend tells you that he has tender, swollen "glands" along the left side of the front of his neck. You notice that he has a bandage on his left cheek that is not fully hiding a large infected cut there. The glands are not really glands. Exactly what are his swollen "glands," and how did they become swollen?
2. When young Joe went sledding, the runner of a friend's sled hit him in the left side and ruptured his spleen. Joe almost died before he got to a hospital. What is the immediate danger of a ruptured spleen?
3. The man in the hospital bed next to Joe is an alcoholic with cirrhosis of the liver and portal hypertension. His spleen is seriously enlarged. Based on what you learned in Chapter 20 (p. 608), how could portal hypertension lead to splenomegaly?
4. Mrs. Roselli has undergone a left radical mastectomy. Her left arm is severely swollen and painful, and she is unable to raise it higher than her shoulder. (a) Explain the origin of her signs and symptoms. (b) Is she likely to have relief from these symptoms in time? Explain.
5. Traci arrives at the clinic complaining of pain and redness of her right ring finger. The finger and the dorsum of her hand have edema, and red streaks are apparent on her right forearm. Antibiotics are prescribed, and the nurse applies a sling to the affected arm. Why is it important that Traci not move the affected arm excessively?
6. Simi realized she was very ill. During a recent trip to the tropics, she had contracted both malaria and tuberculosis, diseases whose microorganisms travel throughout the bloodstream. Back home for only a week, she then contracted mononucleosis. When she went to the doctor, he was able to feel the notched superior border of her spleen projecting far anterior to the left costal margin in her abdominal wall. Was something wrong with her spleen? Explain.



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The Respiratory System

22

Functional Anatomy of the Respiratory System 636

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Disorders of the Respiratory System 657

- Bronchial Asthma 657
- Cystic Fibrosis 657
- Chronic Obstructive Pulmonary Disease 659
- Epistaxis 660

The Respiratory System Throughout Life 660

Humans can live without water for days and without food for weeks, but they cannot live without oxygen for even a few minutes. Breathing is our most urgent need. The trillions of cells in the body need a continuous supply of oxygen to produce the energy needed to carry out their vital functions. Furthermore, as the cells use oxygen, they produce carbon dioxide, a waste product the body must eliminate. The major function of the **respiratory system** is to fulfill these needs—that is, to supply the body with oxygen and dispose of carbon dioxide (CO₂). To accomplish this, the following processes, collectively called **respiration**, must occur:



Bronchial tree of a healthy human lung (colored X ray).

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 22.

PAL = Practice Anatomy Lab™

1. Respiration involves the delivery of O_2 to the body cells for use in energy production and the removal of the waste product CO_2 . The respiratory processes are as follows: pulmonary ventilation, external respiration, cardiovascular transport of respiratory gases, internal respiration, and cellular respiration. Both the respiratory system and the cardiovascular system participate in respiration.

Functional Anatomy of the Respiratory System (pp. 636–654)

2. The organs of the respiratory system include a conducting zone (nose to terminal bronchioles), which warms, moistens, and filters the inhaled air, and a respiratory zone (respiratory bronchioles to alveoli), where gas exchange occurs.

The Nose and the Paranasal Sinuses (pp. 637–640)

3. The nose and nasal cavity provide an airway for respiration and house the olfactory receptors.
4. The external nose is shaped by bone and by cartilage plates. The nasal cavity begins at the external nares and ends posteriorly at the posterior nasal apertures (choanae). Air-swirling conchae occupy its lateral walls. The paranasal sinuses drain into the nasal cavity.
5. The respiratory mucosa lines the nasal cavity and paranasal sinuses. Its epithelium, a pseudostratified ciliated columnar epithelium with goblet cells, is covered with a sheet of mucus that filters dust particles and moistens inhaled air. Its lamina propria contains glands that contribute to the mucus sheet and blood vessels that warm the air.

The Pharynx (pp. 640–641)

6. The pharynx has three regions: The nasopharynx (behind the nasal cavity) is an air passageway; the oropharynx (behind the mouth) and the laryngopharynx (behind the larynx) are passageways for both food and air.
7. The soft palate moves superiorly to seal off the nasopharynx during swallowing. The tubal and pharyngeal tonsils occupy the mucosa that lines the nasopharynx. The oropharynx contains the lingual and palatine tonsils. The laryngopharynx opens into the larynx anteriorly and into the esophagus inferiorly.

The Larynx (pp. 641–644)

8. The larynx, or voice box, is the entryway to the trachea and lower respiratory tubes. The larynx has a skeleton of nine cartilages: the thyroid; the cricoid; the paired arytenoid, corniculate, and cuneiform cartilages; and the epiglottis.
9. The leaf-shaped epiglottis acts as a lid that prevents food or liquids from entering the lower respiratory channels. The larynx moves superiorly under this protective flap during swallowing.
10. The larynx contains the vocal folds (vocal cords). Exhaled air causes these folds to vibrate, producing the sounds of speech. The vocal folds extend anteriorly from the arytenoids to the thyroid cartilage, and muscles that move the arytenoids change the tension on the folds to vary the pitch of the voice. The pharynx, nasal cavity, lips, and tongue also aid in vocal articulation.

11. The main sensory and motor nerves of the larynx (and of speech) are the left and right recurrent laryngeal nerves, which are branches of the vagus nerves.

The Trachea (pp. 644–645)

12. The trachea, which extends from the larynx in the neck to the main bronchi in the thorax, is a tube reinforced by C-shaped cartilage rings, which keep it open. The trachealis muscle narrows the trachea, increasing the speed of airflow during coughing and sneezing.
13. The wall of the trachea contains several layers: a mucous membrane, a submucosa, a fibromusculocartilaginous layer, and an outer adventitia. The mucous membrane consists of an air-filtering pseudostratified ciliated columnar epithelium and a lamina propria rich in elastic fibers.

The Bronchial Tree (pp. 645–649)

14. The right and left main (primary) bronchi supply the lungs. Within the lungs, they subdivide into lobar (secondary) bronchi to the lobes, segmental (tertiary) bronchi to the bronchopulmonary segments, and finally to bronchioles and terminal bronchioles.
15. As the respiratory tubes become smaller, the cartilage in their walls is reduced and finally lost (in bronchioles); the epithelium thins and loses its air-filtering function (in the terminal bronchioles); smooth muscle becomes increasingly important; and elastic fibers continue to surround all of the tubes.
16. The terminal bronchioles lead into the respiratory zone, which consists of respiratory bronchioles, alveolar ducts, and alveolar sacs, all of which contain tiny chambers called alveoli. Gas exchange occurs in the alveoli, across the thin respiratory membrane. The respiratory membrane consists of alveolar type I cells, fused basement membranes, and capillary endothelial cells.
17. Alveoli also contain alveolar type II cells, which secrete surfactant, and freely wandering alveolar macrophages that remove dust particles that reach the alveoli.

The Lungs and Pleurae (pp. 649–653)

18. The lungs flank the mediastinum in the thoracic cavity. Each lung is suspended in a pleural cavity by its root (the vessels supplying it) and has a base, an apex, and medial and costal surfaces. The root structures enter the lung hilum.
19. The right lung has three lobes (superior, middle, and inferior lobes, as defined by the oblique and horizontal fissures); the left lung has two lobes (superior and inferior lobes, as defined by the oblique fissure). The lobes are divided into bronchopulmonary segments, which are supplied by segmental bronchi.
20. The lungs consist primarily of air tubes and alveoli, but they also contain a stroma of elastic connective tissue.
21. The pulmonary arteries carry deoxygenated blood and generally lie posterior to their corresponding bronchi within the lungs. The pulmonary veins, which carry oxygenated blood, tend to lie anterior to their corresponding bronchi. The lungs are innervated by sympathetic and parasympathetic fibers through the pulmonary plexus.
22. Pleurae are serous membranes. The parietal pleura lines the thoracic wall, diaphragm, and mediastinum; the visceral pleura covers the external surfaces of the lungs. The slitlike pleural cavity between the parietal and visceral pleura is filled with a serous fluid

that holds the lungs to the thorax wall and reduces friction during breathing movements. Inferiorly, the pleural cavity extends below the inferior border of the lungs.

PAL Human Cadaver/Respiratory System

Ventilation (pp. 653–657)

The Mechanism of Ventilation (pp. 653–656)

23. Ventilation consists of inspiration and expiration. Inspiration occurs when the diaphragm and intercostal muscles contract, increasing the volume of the thorax. As the intrathoracic pressure drops, pressure in the lungs also drops and air rushes into the lungs.
24. Expiration is largely passive, occurring as the inspiratory muscles relax. The volume of the thorax decreases and the lungs recoil elastically, raising pressure and expelling air from the lungs.
25. Surface tension of the alveolar fluid threatens to collapse the alveoli after each breath. This tendency is resisted by surfactant secreted by alveolar type II cells.

Neural Control of Ventilation (pp. 656–657)

26. The main respiratory control center is in the reticular formation of the medulla oblongata, although this center is influenced by input from the pons, limbic system, hypothalamus, and cerebral cortex.
27. Chemoreceptors monitor concentrations of respiratory gases and acid in the blood. The central chemoreceptors are neurons in the medulla, and the peripheral chemoreceptors are the carotid and aortic bodies.

Disorders of the Respiratory System (pp. 657–660)

28. Bronchial asthma is a chronic, allergic inflammatory condition.
29. Cystic fibrosis is an inherited disease in which the functions of the body's exocrine glands are disrupted. It involves an oversecretion

of a viscous mucus in the bronchi, in which bacteria grow, leading to early death through respiratory infection.

30. Chronic bronchitis, a COPD, is characterized by an excessive production of mucus in the lower respiratory passages, which impairs ventilation and leads to infection. Patients may become cyanotic as a result of low oxygen levels in the blood.
31. Obstructive emphysema, also a COPD, is characterized by permanent enlargement and destruction of alveoli. The lungs lose elasticity, and expiration becomes an active, exhaustive process.
32. Most lung cancers are caused by smoking. They are extremely aggressive, metastasize rapidly, and are most often fatal.
33. Epistaxis (nosebleed) results from trauma to the nose or drying of the nasal mucosa.

The Respiratory System Throughout Life (pp. 660–661)

34. The nasal cavity develops from the olfactory placodes; the pharynx forms as part of the foregut; and the lower respiratory tubes grow from an outpocketing of the embryonic pharynx (laryngotracheal bud). The epithelium lining the pharynx and the lower respiratory tubes derives from endoderm. Mesoderm forms all other parts of these tubes and the lung stroma as well.
35. The respiratory system completes its development very late in the prenatal period: No alveoli or surfactant appear until month 6, and only one-sixth of the final number of alveoli are present at birth. Respiratory immaturity, especially a lack of surfactant, is a serious complication of premature birth.
36. With age, the nose dries, the thorax becomes more rigid, the lungs become less elastic, and ventilation capacity declines. Respiratory infections become more common in old age.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. When the inspiratory muscles contract, (a) only the lateral dimension of the thoracic cavity increases, (b) only the anteroposterior dimension of the thoracic cavity increases, (c) the volume of the thoracic cavity decreases, (d) both the lateral and the anteroposterior dimensions of the thoracic cavity increase, (e) the diaphragm bulges superiorly.
2. The part of the respiratory mucosa that warms the inhaled air is the (a) pseudostratified epithelium, (b) vessels in the lamina propria, (c) alveolar type I cells, (d) cartilage and bone.
3. Which of the following statements about the vocal cords is *false*? (a) They are the same as the vocal folds. (b) They attach to the arytenoid cartilages. (c) Exhaled air flowing through the glottis vibrates them to produce sound. (d) They are also called the vestibular folds.
4. In both lungs, the surface that is the largest is the (a) costal, (b) mediastinal, (c) inferior (base), (d) superior (apex).
5. Match the proper type of lining epithelium from the key with each of the following respiratory structures.

Key: a. stratified squamous c. simple squamous
b. pseudostratified columnar d. stratified columnar

- (1) nasal cavity
— (2) nasopharynx
— (3) laryngopharynx
— (4) trachea and bronchi
— (5) alveoli (type I cells)
6. Match the air tube in column B with the lung region in column A supplied by that air tube.

Column A

- (1) bronchopulmonary segment
— (2) lobule
— (3) alveolar ducts and sacs
— (4) whole lung
— (5) lobe

Column B

- (a) main bronchus
(b) lobar bronchus
(c) segmental bronchus
(d) large bronchiole
(e) respiratory bronchiole
7. The respiratory membrane consists of (a) alveolar type I cell, basement membranes, endothelial cell; (b) air, connective tissue, lung; (c) type II cell, macrophage, type I cell; (d) pseudostratified epithelium, lamina propria, capillaries.
8. The trachealis muscle and the smooth muscle around the bronchi develop from which of the following embryonic layers? (a) ectoderm, (b) endoderm, (c) mesoderm, (d) neural crest.

9. A serous cell of a gland secretes (a) the slippery serous fluid in the body cavities, (b) mucus, (c) a watery lubricating fluid, (d) tissue fluid.
10. The function of alveolar type I cells is to (a) produce surfactant, (b) propel sheets of mucus, (c) remove dust particles through phagocytosis, (d) allow rapid diffusion of respiratory gases.

Short Answer Essay Questions

11. Trace the route of exhaled air from an alveolus to the external nares, naming all the structures through which the air passes. Then indicate which of these structures are in the respiratory zone and which are in the conducting zone.
12. The cilia lining the upper respiratory passages (superior to the larynx) beat inferiorly, whereas the cilia lining the lower respiratory passages (larynx and inferior) beat superiorly. What is the functional reason for this difference?
13. What is the function of the abundant elastin fibers that occur in the stroma of the lung and around all respiratory tubes from the trachea through the respiratory tree?

14. (a) Which tonsils lie in the fauces of the oropharynx? (b) Does the lingual tonsil lie near the superior part of the epiglottis? Explain.
15. (a) It is easy to confuse the hilum of the lung with the root of the lung. Define both structures, and contrast hilum and root. (b) Define the parietal pleura and the visceral pleura.
16. The three terms choanae, conchae, and carina are easily confused. Define each of them, clarifying the differences.
17. Briefly explain the anatomical reason why most men have deeper voices than boys or women.
18. Sketch a picture of the right and left lungs in anterior view, showing all the fissures and lung lobes, as well as the cardiac notch.
19. Explain the functions of the pseudostratified epithelium of the respiratory mucosa.
20. What is the function of the alveolar macrophages in the lung alveoli?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. (a) Two girls in a high school cafeteria were giggling over lunch, and milk accidentally sprayed out of the nostrils of one of them. Explain in anatomical terms why swallowed fluids can sometimes come out the nose. (b) A boy in the same cafeteria then stood on his head to show he could drink milk upside down without any of it entering his nasal cavity or nose. What prevented the milk from flowing downward into his nose?
2. A surgeon had to remove three adjacent bronchopulmonary segments from the left lung of a patient with tuberculosis. Even though almost half of the lung was removed, there was no severe bleeding, and relatively few blood vessels had to be cauterized (closed off). Why was this surgery so easy to perform?
3. While getting his 1-year-old daughter (who puts almost everything in her mouth) ready for bed, Mr. Gregoire could not find one of the small barrettes he had just removed from her hair. Two days later, she developed a cough and became feverish. What probably had happened to the barrette, and where (anatomically) would you expect to find it?
4. A taxi driver was carried into an emergency room after being knifed once in the left side of the thorax. The diagnosis was pneumothorax and a collapsed lung. (a) Explain exactly why the lung collapsed. (b) Explain why only one lung (not both) collapsed.
5. A man was driving to work when his car was hit broadside by a car that ran a red light. When freed from the wreckage, the man was deeply cyanotic, and his breathing had stopped. His heart was still beating, but his pulse was fast and thready. His head was cocked at

a peculiar angle, and the emergency personnel said he seemed to have a fracture at the level of vertebra C₂. (a) How might these findings account for the cessation of breathing? (b) Define cyanosis (see Chapter 5), and indicate why the man was cyanotic.

6. After a 4-year-old child had surgery that successfully closed off a patent ductus arteriosus (see p. 612), the child's voice was hoarse, and an examination revealed that many muscles in the left half of the larynx were paralyzed. What had gone wrong during surgery to cause the paralysis?



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The Digestive System

23

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The goblet cell surface of the jejunum showing a region of microvilli and the surrounding absorptive cells (SEM). © Kessel & Kardon/Visuals Unlimited.

Evidence suggests that diets high in plant fiber decrease the incidence of colon cancer.

check your understanding

20. Why is it so important to wash your hands after using the restroom?

21. What embryonic germ layer forms the epithelium of the mucosa? What germ layer forms the submucosa and muscularis externa?
22. What blood vessel supplies the structures derived from the embryonic midgut?

For answers, see Appendix B.

RELATED CLINICAL TERMS

ANAL FISSURE A longitudinal tear in the mucosa of the anal canal, often caused by the passage of hard, dry feces. Usually heals naturally, but most fissures that do not heal are in the posterior midline, which is poorly vascularized. Symptoms include pain and bleeding during defecation. Treatment includes using laxatives to soften the feces, glycerin suppositories, or in persistent cases, surgery.

ASCITES (ah-si'tēz; *asci* = bag, bladder) Abnormal accumulation of serous fluid that has leaked out of peritoneal capillaries into the peritoneal cavity; may be caused by portal hypertension following liver cirrhosis or by heart or kidney disease. Excessive ascites causes visible bloating of the abdomen.

ENDOSCOPY (en-dos'ko-pe; *endo* = inside; *scopy* = viewing) The viewing of the lining of a ventral body cavity or tubular organ with a flexible, tubelike device called an endoscope, which contains a lens and a light radiating from its tip. Endoscopes are used to view the internal surfaces of various parts of the alimentary canal, including the stomach (gastroscopy), the colon (colonoscopy), and the sigmoid colon (sigmoidoscopy). **Laparoscopy** (lap'ah-ros'ko-pe; "flank viewing") is the use of an endoscope inserted into the peritoneal cavity through the anterior abdominal wall, typically to assess the condition of the digestive organs and the pelvic reproductive organs in women.

ENTERITIS (*enteron* = intestine) Inflammation of the intestine, especially the small intestine.

LIVER BIOPSY (bi'op-se; *bio* = living; *opsis* = vision, viewing) Removal from the liver of a small piece of living tissue, which is then examined for signs of disease. The puncturing needle is inserted through the seventh, eighth, or ninth intercostal space, in the right midaxillary line (straight inferiorly from the axilla) after the patient has exhaled as much air as possible. (Exhalation minimizes the chances that the needle will pierce the lung.)

PYLORIC STENOSIS (*stenosis* = narrowing, constriction) Congenital condition in about 1 in 400 newborns, in which the pyloric sphincter of the stomach is abnormally constricted; the condition's characteristic sign, projectile vomiting, usually does not appear until the baby begins to eat solid food. This condition can usually be repaired surgically. Can also occur in adults through scarring caused by an ulcer or by a tumor that blocks the pyloric opening.

RECTOCELE (rek'to-sēl; *recto* = rectum; *cele* = sac) Condition in women in which the rectum pushes on the vagina and bulges into the posterior vaginal wall. Usually results from tearing of the supportive muscles of the pelvic floor during childbirth, which then allows the unsupported pelvic viscera to sink inferiorly. May also be associated with *rectal prolapse*, in which the rectal mucosa protrudes from the anus.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 23.

PAL = Practice Anatomy Lab™

Overview (pp. 666–671)

1. The digestive system includes the alimentary canal (mouth, pharynx, esophagus, stomach, and small and large intestines) and accessory digestive organs (teeth, tongue, salivary glands, liver, gallbladder, and pancreas).

Digestive Processes (pp. 667–668)

2. The digestive system carries out the processes of ingestion, propulsion, mechanical digestion, chemical digestion, absorption, and defecation.

Abdominal Regions (p. 668)

3. The nine regions of the anterior abdominal wall are defined by two horizontal planes (subcostal and transtubercular planes) and by the vertical midclavicular lines. There are one epigastric and two hypochondriac regions superiorly, one umbilical and two lumbar regions in the middle, and one hypogastric (pelvic) and two iliac

(inguinal) regions inferiorly. The anterior abdominal wall can also be divided into four quadrants.

The Peritoneal Cavity and Peritoneum (pp. 669–671)

4. The serous membrane in the abdominopelvic cavity is the peritoneum, which has a parietal layer (on the internal surface of the body wall) and a visceral layer (on the viscera). The slit between the visceral and parietal peritoneum, the peritoneal cavity, contains slippery serous fluid, which decreases friction as the organs move.
5. A mesentery is a double layer of peritoneum that tethers the movable digestive organs to the body wall. Mesenteries also store fat and carry blood vessels and nerves.
6. The mesenteries associated with the intraperitoneal abdominal organs are (1) the ventral mesenteries, the falciform ligament and lesser omentum; and (2) the dorsal mesenteries, the greater omentum, mesentery proper, transverse mesocolon, and sigmoid mesocolon. Digestive organs that lack a mesentery and are fused to the posterior body wall are called secondarily retroperitoneal organs.

Anatomy of the Alimentary Canal (pp. 671–692)

Histology (pp. 671–673)

7. The esophagus, stomach, and intestine share the same tissue layers: an inner mucosa, a fibrous submucosa, a muscularis externa, and an outer serosa (visceral peritoneum) or adventitia. The mucosa consists of a lining epithelium, lamina propria, and muscularis mucosae.

Smooth Muscle (pp. 673–675)

8. Smooth muscle fibers are elongated cells with tapering ends and one central nucleus. They have no striations or sarcomeres, but are filled with myofilaments that contract by the sliding filament mechanism. Intermediate filaments of the cytoskeleton run in lattice-like arrangement through the cell and beneath the sarcolemma. Actin myofilaments attach to these filaments at dense bodies.
9. Smooth muscle fibers are most often arranged in circular and longitudinal sheets.
10. Smooth muscle contracts for extended periods at low energy cost and without fatigue.
11. Smooth muscle is innervated by involuntary nerve fibers, which usually contact only a few muscle fibers per sheet. The impulse that signals contraction usually spreads from fiber to fiber through gap junctions. This is called single-unit innervation.
12. Visceral motor neurons do not form elaborate neuromuscular junctions with the visceral muscle and glands they innervate. Their axon terminals (varicosities) may even end some distance from the effector cells.
13. Visceral nerve plexuses (myenteric and submucosal) occur in the wall of the alimentary canal. These plexuses contain parasympathetic, sympathetic, and visceral sensory fibers as well as enteric neurons.

The Mouth and Associated Organs (pp. 675–680)

14. Food enters the alimentary canal through the mouth (oral cavity), which consists of an external vestibule and an internal oral cavity proper.
15. The mouth is lined by a stratified squamous epithelium, which resists abrasion by food fragments.
16. The lips and cheeks keep food inside the mouth during chewing. The red margin is the red part of the lips that borders the oral orifice.
17. The tongue is predominantly a mucosa-covered skeletal muscle. Its intrinsic muscles change its shape, and its extrinsic muscles change its position. Three classes of papillae occur on the tongue's superior surface: filiform papillae, which grip food during chewing, and fungiform and circumvallate papillae, which contain taste buds.
18. Saliva is produced by intrinsic salivary glands in the oral mucosa and by three pairs of large extrinsic salivary glands—the parotid, submandibular, and sublingual glands. The salivary glands are compound tubuloalveolar glands containing varying amounts of serous and mucous cells.
19. Teeth tear and grind food in the chewing process (mastication). The 20 deciduous teeth begin to fall out at age 6 and are gradually replaced during childhood and youth by the 32 permanent teeth.
20. Teeth are classified as incisors, canines, premolars, and molars. Each tooth has an enamel-covered crown and a cementum-covered root. The bulk of the tooth is dentin (dentine), which surrounds the central pulp cavity. A periodontal ligament (periodontium) secures the tooth to the bony alveolus.

The Pharynx (p. 680)

21. During swallowing, food passes from the mouth through the oropharynx and laryngopharynx, which are lined by a stratified squamous epithelium. The pharyngeal constrictor muscles squeeze food into the esophagus during swallowing.

The Esophagus (pp. 680–682)

22. The esophagus descends from the pharynx through the posterior mediastinum and into the abdomen. There it joins the stomach at the cardiac orifice, where a sphincter prevents superior regurgitation of stomach contents.
23. The esophageal mucosa contains a stratified squamous epithelium. The muscularis consists of skeletal muscle superiorly and smooth muscle inferiorly. The esophagus has an adventitia rather than a serosa.

The Stomach (pp. 682–685)

24. The J-shaped stomach churns food into chyme and secretes HCl and pepsin, which begins the breakdown of food proteins. Lying in the superior left part of the abdomen, its major regions are the cardia, fundus, body, pyloric region, and pylorus (containing the pyloric sphincter). Its right and left borders are the lesser and greater curvatures. When the stomach is empty, its internal surface exhibits rugae.
25. The internal surface of the stomach is lined by simple columnar epithelial cells that secrete mucus and dotted with gastric pits that lead into tubular gastric glands. Secretory cells in the gastric glands include pepsinogen-producing chief cells, parietal cells that secrete HCl, mucous neck cells, and enteroendocrine cells that secrete hormones (including gastrin).
26. The stomach wall is protected against self-digestion and acid by an internal coat of mucus and by the rapid regeneration of its lining epithelium.

The Small Intestine (pp. 685–688)

27. The small intestine is the main site of digestion and nutrient absorption. Its segments are the duodenum, jejunum, and ileum.
28. The duodenum lies secondarily retroperitoneally in the superior right quadrant of the abdomen. The bile duct and main pancreatic duct join to form the hepatopancreatic ampulla and empty into the duodenum through the major duodenal papilla.
29. The small intestine has four features that increase its surface area and allow rapid absorption of nutrients: its great length, circular folds of the mucosa, villi, and abundant microvilli on the absorptive cells. Absorbed nutrients enter capillaries in the core of the villi.
30. The epithelium lining the internal intestinal surface contains absorptive, goblet, and enteroendocrine cells. Between the villi are the intestinal crypts, which secrete intestinal juice and continuously renew the lining epithelium.
31. Other special features of the small intestine are (1) aggregated lymphoid nodules in the ileum and (2) the duodenal mucous glands.

The Large Intestine (pp. 688–693)

32. The large intestine, which concentrates feces by absorbing water, forms an open rectangle around the small intestine. Its subdivisions are the cecum and vermiform appendix, colon (ascending, transverse, descending, and sigmoid), rectum, and anal canal. Special features on the external surface of the colon and cecum are teniae coli, haustra, and epiploic appendages.
33. The cecum lies in the right iliac fossa and contains the ileocecal valve. Attached to the cecum is the vermiform appendix, which contains abundant lymphoid tissue.

34. Near the end of the large intestine, the sigmoid colon enters the pelvis and joins the rectum. The rectum pierces the pelvic floor and joins the anal canal, which ends at the anus. Internally, the rectum contains the transverse rectal folds, and the anal canal contains anal columns, anal valves, the pectinate line, and anal sinuses.
35. The defecation reflex produces a contraction of the rectal walls when feces enter the rectum. During defecation, contraction of the diaphragm and abdominal muscles increases the intra-abdominal pressure and lifts the anal canal. Defecation can be inhibited by the anal sphincters.
36. Like the small intestine, the large intestine is lined by a simple columnar epithelium with absorptive and goblet cells and contains intestinal glands. It lacks villi, secretes more mucus than the small intestine, and contains more lymphoid tissue than the small intestine.

Anatomy of the Accessory Organs (pp. 693–699)

The Liver (pp. 693–697)

37. The liver performs many functions, including processing of absorbed nutrients, secreting fat-emulsifying bile, and removing toxins from the blood.
38. The liver lies in the superior right region of the abdomen. It has diaphragmatic and visceral surfaces and four lobes (right, left, quadrate, and caudate). The quadrate and caudate lobes are parts of the left lobe. The bare area lies against the diaphragm.
39. Most vessels enter or leave the liver through the porta hepatis. Other structures on the visceral surface are the inferior vena cava, hepatic veins, gallbladder, fissure, round ligament, and ligamentum venosum.
40. Classical liver lobules are hexagonal structures consisting of plates of hepatocytes that are separated by blood sinusoids and converge on a central vein. Portal triads (venule branch of portal vein, arteriole branch of hepatic artery, bile duct) occur at most corners of the lobule.
41. Blood flows through the liver in the following sequence: through the branches of the hepatic artery and portal vein, through the sinusoids to supply the hepatocytes, and then to the central veins, hepatic veins, inferior vena cava, and heart. In the sinusoids, Kupffer cells (macrophages) remove bacteria and other foreign material from the blood.
42. Hepatocytes perform almost all liver functions: They manufacture blood proteins; detoxify poisons; metabolize glucose, fats, and amino acids; and produce bile. These liver cells secrete bile into the bile canaliculi. The bile proceeds to the bile ducts in the portal triads, to the hepatic ducts, and through the common hepatic duct to the gallbladder and duodenum.

The Gallbladder (p. 697)

43. The gallbladder, a green muscular sac, stores and concentrates bile. Its duct is the cystic duct. When fatty chyme enters the

small intestine, the gallbladder squeezes bile into the bile duct and duodenum.

The Pancreas (pp. 698–699)

44. The tadpole-shaped pancreas is secondarily retroperitoneal. It runs horizontally across the posterior abdominal wall, between the duodenum and the spleen.
45. The pancreas is an exocrine gland containing many compound acinar glands that empty into the main and accessory pancreatic ducts. The serous acinar cells secrete digestive enzymes, and the smallest duct cells secrete an alkaline fluid. Both products are emptied into the duodenum.
46. The pancreas is also an endocrine gland, with hormone-secreting cells that regulate blood sugar.

PAL = Human Cadaver/Digestive System

Disorders of the Digestive System (pp. 699–700)

47. Disorders considered in this chapter include hiatal hernia of the esophagus, gastroesophageal reflux disease (p. 681), peptic ulcers, intestinal obstruction, inflammatory bowel disease, viral hepatitis, and the obstructive effect of cystic fibrosis on the pancreatic ducts.

The Digestive System Throughout Life (pp. 700–702)

Embryonic Development (pp. 700–701)

48. As the 3-week-old embryo assumes its cylindrical body shape, it encloses the primitive gut, a tube of endoderm covered by splanchnic mesoderm. The endoderm becomes the lining epithelium (and gland cells), and the splanchnic mesoderm gives rise to all other layers of the wall of the alimentary canal and the gut-derived organs.
49. The embryonic gut is divided into a foregut, midgut, and hindgut, which form distinct regions of the digestive system.
50. The primitive embryonic gut tube, straight at first, soon grows out-pocketings (liver, pancreas, pharyngeal pouches), shows swellings (stomach, cloaca), and lengthens into a primitive intestinal loop. This loop rotates and elongates to bring the intestines into their final positions.

The Digestive System in Later Life (pp. 701–702)

51. Various diseases may plague the digestive organs throughout life. Appendicitis is common in young adults; gastroenteritis and food poisoning can occur at any time; and ulcers and gallbladder problems increase in middle age.
52. The efficiency of digestive processes declines in the elderly, and constipation becomes common. Diverticulosis and cancers (such as colon and stomach cancer) appear with increasing frequency among older individuals.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

1. Which of the following organs is secondarily retroperitoneal? (a) pharynx, (b) stomach, (c) ascending colon, (d) ileum.

2. The submucosal nerve plexus of the intestine (a) innervates the mucosa layer, (b) lies in the mucosa layer, (c) controls peristalsis, (d) contains only motor neurons.
3. For each organ in the left-hand column, select the type of epithelium that lines its lumen from the list in the right-hand column.

Organ	Epithelium types
— (1) oral cavity	(a) simple squamous
— (2) oropharynx	(b) simple cuboidal
— (3) esophagus	(c) simple columnar
— (4) stomach	(d) stratified squamous
— (5) small intestine	(e) stratified cuboidal
— (6) colon	

4. Match each of the mesenteries in the key with the appropriate description.

Key:

- | | |
|------------------------|--------------------------|
| (a) greater omentum | (d) mesentery proper |
| (b) lesser omentum | (e) transverse mesocolon |
| (c) falciform ligament | (f) sigmoid mesocolon |
- (1) connects the ileum and jejunum to the posterior abdominal wall
 — (2) connects anterior surface of the liver to the anterior abdominal wall
 — (3) connects the large intestine to the pelvic wall
 — (4) attaches to the greater curvature of the stomach; has the most fat
 — (5) runs from the stomach's lesser curvature to the fissure of the liver
 — (6) a mesentery of the large intestine that is fused to the underside of the greater omentum
5. The pointed type of tongue papilla that is not involved with taste reception is (a) filiform, (b) fungiform, (c) circumvallate, (d) dermal.
6. Which of the following statements about the gallbladder is *false*? (a) It makes bile. (b) Its duct is called the cystic duct. (c) It has a fundus lying inferior to the liver. (d) It has mucosal folds similar to the stomach rugae.
7. Which of the following correctly describe the flow of blood through the classical liver lobule and beyond? (More than one choice is correct.) (a) portal venule to sinusoids to central vein to hepatic vein to inferior vena cava, (b) porta hepatis to hepatic vein to portal venule, (c) portal venule to central vein to hepatic vein to sinusoids, (d) portal arteriole to sinusoids to central vein to hepatic vein.
8. The exocrine glands in the pancreas are (a) simple tubular, (b) simple acinar, (c) compound tubular, (d) compound acinar, (e) compound tubuloalveolar.
9. Which cell type occurs in the stomach mucosa, has three prongs, contains many mitochondria and many microvilli, and pumps hydrogen ions? (a) absorptive cell, (b) parietal cell, (c) mucus-secreting cell, (d) muscularis externa cell, (e) mucous neck cell.
10. Which one of the following features is shared by both the small and large intestines? (a) intestinal crypts, (b) aggregated lymphoid nodules (Peyer's patches), (c) teniae coli, (d) haustra, (e) circular folds, (f) intestinal villi.
11. A digestive organ that has a head, neck, body, and tail is the (a) pancreas, (b) gallbladder, (c) greater omentum, (d) stomach.
12. From the list of abdominal regions listed in column B, indicate the predominant region where each organ listed in column A is found.

Column A	Column B
— (1) small intestine	(a) right hypochondriac
— (2) liver	(b) left hypochondriac
— (3) stomach	(c) right iliac
— (4) ascending colon	(d) right lumbar
— (5) cecum	(e) umbilical

13. Protein digestion begins (a) in the mouth by saliva, (b) in the stomach by pepsin, (c) in the duodenum by bile, (d) in the small intestine by intestinal secretions.

14. The calcified connective tissue that attaches the tooth to the periodontal ligament is the (a) pulp, (b) enamel, (c) dentine, (d) cementum, (e) periodontium.

15. Which of the following statements about smooth muscle is false? (a) Smooth muscle cells are called fibers. (b) Most smooth muscle cells, like cardiac muscle cells, are joined by gap junctions. (c) Smooth muscle cells have a single, centrally located nucleus. (d) Contraction of smooth muscle is stimulated exclusively by involuntary nerves. (e) Smooth muscle tissue found in the wall of hollow organs is arranged in sheets.

16. Match the digestive organ listed in column B with the function listed in column A.

Column A	Column B
— (1) produces bile	(a) salivary glands
— (2) absorbs water	(b) esophagus
— (3) churning occurs here	(c) stomach
— (4) muscular tube connecting the laryngopharynx with the stomach	(d) small intestine
— (5) produces both endocrine and exocrine secretions	(e) liver
— (6) secretes a substance that initiates carbohydrate digestion	(f) gallbladder
— (7) stores bile	(g) pancreas
— (8) segmentation occurs here	(h) large intestine

17. The salivary gland that contains only serous cells is the (a) parotid gland, (b) submandibular gland, (c) sublingual gland, (d) intrinsic gland.
18. Use the key below to indicate the blood vessel that supplies arterial blood to each of the digestive organs listed.

Key:

- | | |
|--------------------------------|--|
| (a) celiac trunk | |
| (b) superior mesenteric artery | |
| (c) inferior mesenteric artery | |
- | | |
|------------------------|-----------------------|
| — (1) stomach | — (5) ascending colon |
| — (2) ileum | — (6) rectum |
| — (3) descending colon | — (7) cecum |
| — (4) liver | |

Short Answer Essay Questions

19. Make a simple drawing of the organs of the alimentary canal, and label each organ. Also label the gross subparts of the stomach and intestines. Then add three more labels to your drawing—*salivary glands*, *liver*, and *pancreas*—and use arrows to show where each of these three glandular organs empties its secretion into the alimentary canal.
20. Name the layers of the wall of the alimentary canal. Describe the tissue composition and the major function of each layer. Then, identify the embryonic source of each layer.
21. (a) Write the dental formulas for both the deciduous and the permanent teeth. (b) Define dental pulp and describe its location.
22. Bianca went on a trip to the Bahamas during spring vacation and did not study for her anatomy test scheduled early the following week. On the test, she mixed up the following pairs of structures: (a) the rectal valves and the anal valves, (b) pyloric region and pylorus of the stomach, (c) anal canal and anus, (d) villi and microvilli (in the small intestine), (e) hepatic vein and hepatic portal vein, (f) gastric pits and gastric glands. Help her by defining and differentiating between these sound-alike structures.
23. (a) Make a rough sketch of the visceral surface of the liver, and label the following five structures: fissure, porta hepatis, inferior vena cava, gallbladder, caudate lobe. (b) To follow up on part (a), it is easy to learn the structure of the visceral surface of the liver if you can find and mark the big H there. To mark the left vertical limb of the H, draw a line through the fissure. To mark the crossbar of the H, draw a horizontal line through the porta hepatis. Then, to mark the right limb of the H, draw a continuous vertical line through the inferior vena cava and gallbladder. Which two lobes are inside the H? Which limb of the H separates the liver's right and left lobes?
24. Name four structural features that increase the absorptive surface area of the small intestine.
25. (a) List the three major vessels of the portal triad, and describe the location of this triad with respect to the liver lobule. (b) Name three organelles that are abundant within hepatocytes, and explain how each of these organelles contributes to liver functions.
26. Of the three big extrinsic salivary glands, which is the largest? Which one underlies the tongue? Which has only serous glands?
27. Trace the entire duct systems of the liver and pancreas. (Study these ducts in Figure 23.19, and then try to draw them from memory.)
28. On a diagram of the adult digestive tract (such as Figure 23.1), mark the boundaries between the derivatives of the embryonic foregut, midgut, and hindgut.
29. Where in the alimentary canal does chemical digestion begin for each of the three types of food: carbohydrates, proteins, and fats?
30. List all of the sphincters in the gastrointestinal tract and indicate the location of each.
31. Name the five processes of digestion and indicate all the locations in the gastrointestinal tract where each process occurs.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. This chapter describes schemes that divided the anterior abdominal wall into nine regions or four quadrants. List the regions that lie either entirely or partially within (a) the upper right quadrant and (b) the lower left quadrant.
2. A 21-year-old man with severe appendicitis did not seek treatment in time and died a week after his abdominal pain and fever began. Explain why appendicitis can quickly lead to death.
3. Duncan, an inquisitive 8-year-old, saw his grandfather's dentures soaking overnight in a glass of water. He asked his grandfather how his real teeth had fallen out. Assuming the grandfather remembered the events correctly but was not a medical expert and used layperson's terms, reconstruct the kind of story the man is likely to have told.
4. Eva, a middle-aged attorney, complains of a burning pain in the "pit of her stomach," usually beginning about 2 hours after eating and lessening after she drinks a glass of milk. When asked to indicate the site of pain, she points to her epigastric region. When her GI tract is examined by endoscopy, a gastric ulcer is visualized. What are the possible consequences of nontreatment?
5. A doctor used an endoscope and located some polyps (precancerous tumors) in the wall of the large intestine of an elderly man. What is an endoscope?
6. The janitor who cleaned the anatomy lab had a protruding abdomen that looked like the biggest "beer-belly" the students had ever seen, even though the rest of his body did not look fat at all. Another janitor on the floor told some students that the man was a recovering alcoholic and that he had "over a hundred pounds of fluid in his belly." What was the man's probable condition? (See this chapter's Related Clinical Terms.)
7. Explain why cancer chemotherapies that stop the replication of cellular DNA throughout the body cause nausea, diarrhea, and vomiting.
8. From what embryonic layer (ectoderm, mesoderm, or endoderm) are the hepatocytes of the liver and the pancreatic acinar cells and islets derived?
9. Why is dehydration a concern for an individual with persistent diarrhea?
10. Rebound tenderness in the lower right quadrant of the abdomen is an indication of what disorder?



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The Urinary System

24

Kidneys 708

Gross Anatomy of the Kidneys 708

Microscopic Anatomy of the Kidneys 711

Ureters 718

Gross Anatomy 718

Microscopic Anatomy 718

Urinary Bladder 719

Gross Anatomy 719

Microscopic Anatomy 720

Urethra 720

Micturition 721

Disorders of the Urinary System 723

Urinary Tract Infections 723

Renal Calculi 723

Cancer of Urinary Organs 723

The Urinary System Throughout Life 724

The kidneys maintain the purity and chemical constancy of the blood and the other extracellular body fluids. Much like a water purification plant that keeps a city's water drinkable and disposes of its wastes, the kidneys are usually unappreciated until they malfunction and body fluids become contaminated. Every day, the kidneys filter many liters of fluid from the blood, sending toxins, metabolic wastes, excess water, and excess ions out of the body in urine while returning needed substances from the filtrate to the blood. The main waste products excreted in urine are



Angiogram of the kidney (colored X ray).

RELATED CLINICAL TERMS

CYSTOCELE (sis-to'-sél) (cyst = the bladder; cele = sac, hernia)

Condition in women in which the urinary bladder pushes on the vagina and bulges into the anterior superior vaginal wall; may result from tearing of the supportive muscles of the pelvic floor during childbirth, which then causes the unsupported pelvic viscera to sink inferiorly. This condition changes the position of the upper urethra in ways that can lead either to urinary retention or incontinence; a tearing or weakening of the external urethral sphincter also promotes stress incontinence.

CYSTOSCOPY (sis-tos'ko-pe) The threading of a thin viewing tube through the urethra into the bladder to examine the surface of the bladder mucosa. Can detect bladder tumors, kidney stones, and infections.

DIALYSIS (di-al'ĭ-sis) A technique for removing wastes from the blood and replenishing acid-base buffers in individuals with failing kidneys; involves the diffusion of solutes across a membrane situated between the blood and a dialysis solution. The membrane can be either in an artificial kidney machine, through which the patient's blood is run (a process called *hemodialysis*), or in the patient's own peritoneum

(a process called *peritoneal dialysis*). In the latter case, the dialysis fluid is injected into the patient's peritoneal cavity and removed when it has accumulated wastes.

RENAL INFARCT Area of dead (necrotic) renal tissue; may result from infection, hydronephrosis, or blockage of the blood supply to the kidney; commonly caused by blockage of an interlobar artery, which lacks anastomoses.

VESICoureTERIC REFLUX (ves'ĭ-ko-u-re'ter-ik; "bladder to ureter")

Abnormal backflow of urine from the bladder into the ureter during micturition. In infants, it often reflects a congenital abnormality of the valve mechanism of the ureters in the bladder wall (see p. 718). When it appears in adults, it can result from increased pressures during voiding or from an obstruction of the urethra. Reflux can lead to pressure damage in the kidneys, kidney stones, and infection of the entire urinary tract as bacteria are flushed upward from the urethra. Treatment is with antibiotics, surgical reconstruction of the vesicoureteric valves or, in severe cases, by moving the end of the ureter so that it empties into the intestine.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 24.

PAL = Practice Anatomy Lab™

1. In forming urine, the kidneys cleanse the blood of nitrogenous wastes, toxins, excess ions and water, and other unnecessary or undesirable substances. Kidneys also maintain the proper chemical composition of the blood and other body fluids. The organs for transporting and storing urine are the ureters, the bladder, and the urethra.

Kidneys (pp. 708–718)

Gross Anatomy of the Kidneys (pp. 708–711)

2. The bean-shaped kidneys lie retroperitoneally in the posterior abdominal wall, extending from the level of T₁₁ or T₁₂ to L₃.
3. The supportive and protective layers around the kidney are the fibrous capsule, the perirenal fat capsule, and the renal fascia.
4. A kidney has an external cortex, a deeper medulla consisting of renal pyramids, and a medial renal sinus that contains the main vessels and nerves of the kidney as well as the renal pelvis (the wide upper part of the ureter). Tributaries of the renal pelvis, the major and minor calices, collect urine draining from the papillae of the medullary pyramids. The medial, slitlike opening of the renal sinus is the hilum.
5. The vascular pathway through a kidney is as follows: renal artery → segmental arteries → interlobar arteries → arcuate arteries → cortical radiate arteries → afferent arterioles → glomeruli → efferent arterioles → peritubular capillary beds (or vasa recta) → cortical radiate veins → arcuate veins → interlobar veins → renal vein.
6. The nerve supply of the kidneys, consisting largely of sympathetic fibers, is from the renal plexus.

Microscopic Anatomy of the Kidneys (pp. 711–718)

7. The production of urine by the nephron involves three processes: filtration (which produces a filtrate of the blood that is modified into urine); resorption (which reclaims the desirable molecules from the filtrate and returns them to the blood); and secretion (in which undesirable molecules are pumped from the peritubular capillaries into the nephron).
8. The main structural and functional unit of the kidney is the nephron. The nephron, which forms the urine, consists of a renal corpuscle and a renal tubule. The renal tubule is composed of a proximal convoluted tubule, a nephron loop (loop of Henle), a distal convoluted tubule, and the collecting duct.
9. Filtration occurs at the renal corpuscles in the renal cortex. Each renal corpuscle consists of a glomerulus (a capillary tuft) surrounded by a glomerular capsule. The visceral (inner) layer of this capsule consists of octopus-shaped podocytes, which surround the capillaries of the glomerulus.
10. In passing from the glomerulus to the capsular space, the filtrate passes through the filtration membrane, which consists of the fenestrated glomerular endothelium, the basement membrane, and the filtration slits between podocytes. The main filters are the basement membrane and slit diaphragms covering the filtration slits; these structures retain molecules that are larger than small proteins.
11. From the glomerular capsule, the filtrate enters the proximal convoluted tubule (in the renal cortex), whose simple cuboidal epithelial cells show extreme specializations for resorption and secretion: many long microvilli, many mitochondria, and infoldings of the basolateral plasma membrane.
12. The nephron loop (loop of Henle) extends into the renal medulla. It consists of descending and ascending limbs. The first part of the descending limb, which resembles the proximal tubule, narrows to join the thin segment, whose walls consist of a simple squamous

epithelium. The thin segment joins the thick segment of the ascending limb, which is structurally similar to the distal convoluted tubule.

13. The distal convoluted tubule (in the renal cortex) is active in resorption and secretion, but less so than the proximal tubule. Its simple cuboidal epithelial cells exhibit abundant mitochondria and infoldings of the basolateral membrane, but no elaboration of the surface microvilli.
14. From the distal convoluted tubule, filtrate enters the collecting duct. Collecting ducts play a minor role in resorbing and secreting ions. More importantly, collecting ducts (along with distal tubules) resorb water in response to ADH (antidiuretic hormone) to concentrate urine.
15. There are two kinds of nephrons: cortical and juxtamedullary. The loops of the cortical nephrons extend only a short distance into the medulla. The loops of the juxtamedullary nephrons project deeply into the medulla and contribute to the mechanism that concentrates urine.
16. Each nephron is associated with a glomerulus (the capillary in the renal corpuscle from which the filtrate arises). Also associated with the nephrons are peritubular capillaries (which surround the convoluted tubules and are involved in resorption and secretion) and vasa recta (capillary-like vessels around the nephron loop of juxtamedullary nephrons, which function in concentrating urine). Glomeruli are supplied by afferent arterioles and drained by efferent arterioles, which in turn are continuous with the peritubular capillaries or the vasa recta.
17. The juxtaglomerular apparatus, which occurs at the point of contact between the afferent arteriole and the terminal portion of the ascending limb of the nephron loop, consists of granular cells and a macula densa. It functions in the hormonal correction of low blood pressure and low blood volume.

Ureters (pp. 718–719)

Gross Anatomy (p. 718)

18. The ureters are slender tubes descending retroperitoneally from the kidneys to the bladder. Each ureter enters the true pelvis by passing over the sacroiliac joint.

Microscopic Anatomy (pp. 718–719)

19. From external to internal, the layers of the ureter wall are (1) an adventitia of connective tissue, (2) a muscularis of smooth muscle, and (3) a highly distensible mucosa consisting of a lamina propria and a transitional epithelium. The muscularis squeezes urine inferiorly through the ureters.

Urinary Bladder (pp. 719–720)

Gross Anatomy (pp. 719–720)

20. The urinary bladder, a distensible muscular sac for storing urine, lies in the pelvis just posterior to the pubic symphysis.
21. A full bladder expands superiorly into the abdominal cavity and can be palpated through the anterior abdominal wall superior to the pubic symphysis. An empty bladder is an inverted pyramid with four angles (the neck drains into the urethra, the anterior angle is continuous with the urachus, and the two posterolateral angles are where ureters enter). The trigone is an elevated triangle on the inner surface of the posterior wall that is defined by the ureteric and urethral openings.

Microscopic Anatomy (p. 720)

22. The bladder wall, from internal to external, consists of a mucosa with a transitional epithelium, the detrusor muscle, and an adventitia (or, on the superior surface of the bladder, parietal peritoneum).

Urethra (pp. 720–721)

23. The urethra is the tube that conveys urine from the bladder out of the body. Various types of stratified epithelium line its lumen.
24. Where the urethra leaves the bladder, it is surrounded by the internal urethral sphincter, an involuntary sphincter of smooth muscle. Inferior to this, where the urethra passes through the urogenital diaphragm, it is surrounded by the external urethral sphincter, a voluntary sphincter of skeletal muscle.
25. In females, the urethra is 3–4 cm long and conducts only urine. In males, the urethra is about 20 cm long and conducts both urine and semen.

PAL = Human Cadaver/Urinary System

Micturition (pp. 721–723)

26. Micturition is the act of emptying the bladder.
27. As accumulating urine stretches the bladder, sensory neurons carry this information up the spinal cord to the micturition center in the pons. This center initiates micturition by signaling the parasympathetic neurons to the detrusor muscle.
28. Because the external urethral sphincter is controlled voluntarily, micturition can be delayed temporarily.

Disorders of the Urinary System (pp. 723–724)

29. Disorders of the urinary system include urinary tract infections (in which fecal bacteria spread up the urinary tract), calculi (kidney stones) that precipitate from the urine and can painfully block the ureter, bladder cancer, and kidney cancer.

The Urinary System Throughout Life (pp. 724–725)

30. Three sets of kidneys (pronephric, mesonephric, and metanephric) develop in sequence from the intermediate mesoderm of the embryo. The metanephros—the definitive kidney—forms in the pelvis as the ureteric bud signals nephrons to form in the intermediate mesoderm. The metanephric kidney moves cranially from the pelvis to the lumbar region.
31. The embryonic cloaca forms the urogenital sinus, which becomes both the bladder and the urethra.
32. The kidneys of newborns cannot concentrate urine. Their bladders are small, and voiding is frequent. Neuromuscular maturation generally allows toilet training for micturition to begin by 18 months of age.
33. From youth to middle age, the most common urinary problems are bacterial infections.
34. With age, nephrons are lost, the filtration rate decreases, and the kidneys become less efficient at concentrating urine. The capacity and tone of the bladder decrease with age, leading to frequent voiding and (often) incontinence. Urinary retention is a common problem of elderly men.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- The inferior border of the right kidney is at the level of which vertebra? (a) T₁₂, (b) L₁, (c) L₂, (d) L₃.
- The capillaries of the glomerulus differ from other capillary networks in the body in that they (a) form an anastomosing network, (b) drain into arterioles instead of venules, (c) contain no endothelium, (d) are the only capillaries from which a fluid leaves the blood.
- Which of the following structures occurs exclusively in the renal medulla? (a) renal corpuscles, (b) distal convoluted tubules, (c) vasa recta, (d) proximal convoluted tubules.
- Which of the following extend into the renal pyramid? (a) glomerulus, (b) distal convoluted tubules, (c) nephron loops, (d) proximal convoluted tubules, (e) renal columns.
- The arrangement of the major blood vessels and urine-carrying vessels at the hilum of the kidney (from anterior to posterior) is: (a) renal artery branches, renal pelvis, renal vein; (b) renal vein, renal pelvis, renal artery branches; (c) renal pelvis, renal vein, renal artery branches; (d) renal vein, renal artery branches, renal pelvis.
- The part of the nephron whose epithelial cells contain the longest microvilli and the most mitochondria is the (a) glomerular capsule (podocytes), (b) proximal tubule, (c) thin segment, (d) distal tubule.
- The only part of the nephron that originates from the embryonic ureteric bud is the (a) glomerular capsule, (b) proximal convoluted tubule, (c) nephron loop, (d) distal convoluted tubule, (e) collecting duct.
- The main function of the transitional epithelium in the ureter is (a) not the same as that of the transitional epithelium in the bladder, (b) protection against kidney stones, (c) secretion of mucus, (d) resorption, (e) stretching.
- Jim was standing at a urinal in a crowded public restroom, and a long line was forming behind him. He became anxious (a sympathetic response) and suddenly found he could not micturate no matter how hard he tried. Jim's problem was that (a) his internal urethral sphincter was constricted and would not relax, (b) he had formed a kidney stone on the spot, and it was blocking his urethra, (c) his detrusor muscle was contracting too hard, (d) he almost certainly had a burst bladder.
- A major function of the collecting ducts is (a) secretion, (b) filtration, (c) concentrating urine, (d) lubrication with mucus, (e) stretching.
- Urine passes downward through the ureters by which mechanism(s)? (a) ciliary action, (b) peristalsis and gravity, (c) gravity alone, (d) suction exerted on the ureters and renal pelvis as the bladder expands with urine.
- Parasympathetic stimulation of the bladder causes (a) inhibition of the detrusor muscle and relaxation of the external urethral sphincter, (b) contraction of the detrusor muscle and relaxation of the internal urethral sphincter, (c) relaxation of the internal and external urethral sphincters, (d) contraction of the detrusor muscle and contraction of the internal urethral sphincter.

- Follow the path of filtrate from production in the renal corpuscle to excretion out of the body. Number the structures in the order that filtrate or urine passes through them beginning with #1, formation of filtrate in the glomerular capillaries.

- (a) glomerular capillaries
- (b) collecting duct
- (c) urethra
- (d) proximal convoluted tubule
- (e) papillary duct
- (f) ureter
- (g) glomerular capsule
- (h) distal convoluted tubule
- (i) renal pelvis
- (j) urinary bladder
- (k) nephron loop
- (l) calyx

- Match the renal vessels listed in column B with their location listed in column A.

Column A

- (1) located in the renal columns
- (2) located around the renal tubules
- (3) branches off the renal artery that enter the hilum
- (4) located at the medulla-cortex junction
- (5) located in the renal corpuscle

Column B

- (a) glomerular capillaries
- (b) arcuate arteries and veins
- (c) interlobar arteries and veins
- (d) peritubular capillaries
- (e) segmental arteries

Short Answer Essay Questions

- Name the layers of fat and fascia around the kidney; explain the functions of the fat layers.
- Pairs of urinary structures that are often confused are the ureters and the urethra; the perirenal and pararenal fat; and the renal sinus and renal pelvis. For each pair, differentiate one structure from the other.
- Trace the path taken by the renal filtrate (and urine) from the glomerulus to the urethra. Name every microscopic and gross tube and structure that it passes through on its journey.
- (a) Describe the basic process and purpose of tubular resorption. (b) Explain the location and function of the peritubular capillaries.
- List all the layers of the filtration membrane in a renal corpuscle and describe the function of each layer.
- Name (a) the four angles of the empty bladder and (b) the tube or band that attaches to each angle. (c) What three openings define the trigone of the bladder?
- Define micturition, and describe its neural control.
- Describe the changes that occur in the anatomy and function of the kidney with age.

23. How does the path of the ureters through the bladder wall minimize the chances of vesicoureteric reflux (see Related Clinical Terms) and hydronephrosis occurring (see “The Urinary System Throughout Life”)?
24. Review the types of epithelium found throughout the structures of the urinary system. How does each epithelial type reflect the function of each structure?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Recently, people at risk for developing bladder cancer have been encouraged to drink more fluids. Describe why this lowers one's chances of getting bladder cancer.
2. What is cystitis? Why do women suffer from cystitis more often than men?
3. Hattie, aged 55, is awakened by excruciating pain that radiates from her right abdomen to the lumbar and inguinal regions on the same side. The pain does not occur continuously but recurs at intervals of 3–4 minutes. Diagnose her problem, and cite factors that might favor its occurrence. Also, explain why Hattie's pain comes in “waves.”
4. Felicia, a medical student, arrived late to a surgery in which she was to observe the removal of an extensive abscess from the fat around a patient's kidney. Felicia was startled to find the surgical team working to reinflate the patient's lung and to remove air from the pleural cavity. How could renal surgery lead to such events?
5. Maliki, a radiologist, was examining a pyelogram for renal calculi in a patient's right ureter. Which three regions of the ureter did he scrutinize first?
6. Why should parents teach their young daughters to wipe from front to back after defecation? Why does using a spermicide for birth control increase a woman's chance of getting a urinary tract infection?



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25 The Reproductive System

The Male Reproductive System 731

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- Descent of the Gonads 765
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Human sperm in uterine tube (colored SEM).

Segmentation By \ Belal Shams AlDin

intercourse may become painful, and vaginal infections become more common. The skin thins gradually, and bone mass declines, sometimes resulting in osteoporosis. Slowly rising blood cholesterol levels place postmenopausal women at risk for cardiovascular disorders.

There is no equivalent of menopause in men. Instead, starting at age 40, testosterone production begins a slow decline of about 1% per year. As a result, bone and muscle mass decrease gradually, as does sperm formation—although not enough to prevent some elderly men from fathering children. Erection becomes less efficient as the amount of connective tissue in the penile erectile bodies increases with age.

RELATED CLINICAL TERMS

FIBROIDS Slow-growing, benign tumors in the wall of the uterus made of smooth muscle cells and fibrous connective tissue. Fibroids occur in about 20% of all women over 30. Their precise cause is unknown but may relate to an atypical response to estrogens. Small fibroids produce no symptoms, but large ones can cause pressure and pain in the pelvis, heavy menstrual periods, and infertility. A conservative treatment is myomectomy, removal of the fibroid from its capsule while preserving the rest of the uterus. However, if the fibroids are abundant, the whole uterus may require removal.

HYDROCELE (hi'dro-sēl) (*hydro* = water; *cele* = sac) A swelling in the scrotum caused by an excessive accumulation of fluid in the cavity of the tunica vaginalis; may result from an infection or injury to the testis that causes the layers of the tunica vaginalis to secrete excess serous fluid. Most hydroceles are small and do not require treatment. Large hydroceles can be treated by first aspirating the fluid with a needle inserted into the cavity of the tunica vaginalis and then removing the serous lining of the tunica vaginalis.

HYSTERECTOMY (his'tē-rek'to-me) (*hyster* = uterus; *ectomy* = cut out) Surgical removal of the uterus; a very common operation, typically performed to remove fibroids (25% to 30%), to stop abnormal uterine bleeding (20%), as a treatment for endometriosis (under 20%), and to relieve uterine prolapse (4% to 17%) and chronic pelvic pain (12% to 18%). The uterus can be removed either through

check your understanding

21. What type of screening is most common for each cancer listed here: (a) prostate cancer, (b) cervical cancer, (d) testicular cancer?
22. What do the embryonic mesonephric ducts form in a male embryo? What do the paramesonephric ducts form in a male embryo?
23. What are secondary sex characteristics in males and females, and what stimulates their development?

For answers, see Appendix B.

the anterior abdominal wall or the vagina. In response to evidence that hysterectomies are performed too often, standardized criteria for deciding when they are appropriate have been developed by the American College of Obstetricians and Gynecologists.

ORCHITIS (or-ki'tis) (*orcho* = testis) Inflammation of the testes, sometimes caused by the mumps virus. If testicular infection spreads to the epididymis, it is called epididymo-orchitis.

TESTICULAR TORSION Twisting of the spermatic cord and testis within the scrotum, which can starve the testis of its blood supply and produce sudden urgent pain, swelling, and reddening of the scrotum. It can result from trauma or a spasm of the cremaster muscle and is most common in those males in whom the testis, instead of attaching to the posterior scrotal wall, hangs freely. The twist can be diagnosed by various imaging techniques, but surgery to undo it is often performed without waiting for imaging.

TUBAL LIGATION Having one's uterine tubes "tied" surgically as a form of birth control. Usually involves threading a cutting instrument and a viewing tube (laparoscope) through a small incision in the anterior abdominal wall and then tying and/or cutting the uterine tubes. Tubal ligation usually is irreversible, although in some cases delicate microsurgery can successfully reopen or reattach the uterine tubes.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 25.

PAL = Practice Anatomy Lab™

1. The function of the reproductive system is to produce offspring. The gonads produce gametes (sperm or ova) and sex hormones. All other reproductive organs are accessory organs.

The Male Reproductive System (pp. 731–742)

The Testes (pp. 731–734)

2. The scrotum is the sac of skin and subcutaneous tissue that contains the testes. Housing the testes outside of the body cavity keeps the testes at a slightly lower temperature than the body, as required for viable sperm production. The dartos muscle, cremaster muscle, and pampiniform plexus help regulate the temperature of the testes in the scrotum.

3. Each testis, which is partly surrounded by a serous sac called the tunica vaginalis (derived from the peritoneum), is divided into many lobules that contain sperm-producing seminiferous tubules separated by areolar connective tissue.
4. The thick epithelium of the seminiferous tubule consists of spermatogenic cells (spermatogonia, primary and secondary spermatocytes, and spermatids), embedded in columnar sustentocytes. Spermatogenic cells move toward the tubule lumen as they differentiate into sperm by a process called spermatogenesis.
5. Sustentocytes (Sertoli cells) form the blood-testis barrier, nourish the spermatogenic cells, and move them toward the lumen. They also secrete testicular fluid (for sperm transport), androgen-binding protein, and the hormone inhibin.
6. Myoid cells are smooth-muscle-like cells that surround the seminiferous tubules and help to squeeze sperm through the tubules.

7. Interstitial (Leydig) cells, oval cells in the connective tissue between seminiferous tubules, secrete androgens (mostly testosterone) under the influence of luteinizing hormone from the pituitary gland.

Male Reproductive Ducts (pp. 734–737)

8. From the seminiferous tubules, sperm travel through the straight tubules and rete testes, then out of the testes through the efferent ductules into the epididymis.
9. The comma-shaped epididymis hugs the posterolateral surface of the testis. The duct of the epididymis, lined with a pseudostratified columnar epithelium with stereocilia, is where sperm gain the ability to swim and fertilize. Ejaculation begins with contraction of smooth muscle in the duct of the epididymis.
10. The ductus (vas) deferens extends from the epididymis in the scrotum to the ejaculatory duct in the pelvic cavity. During ejaculation, the thick layers of smooth muscle in its wall propel sperm into the urethra by peristalsis.
11. The fascia-covered spermatic cord contains the ductus deferens and the testicular vessels. It runs through the anterior abdominal wall from the scrotum to the superficial inguinal ring and then continues through the inguinal canal to the deep inguinal ring.
12. The urethra, which runs from the bladder to the tip of the penis, conducts semen and urine to the body exterior.

Accessory Glands (pp. 737–738)

13. The seminal vesicles (seminal glands)—long, pouched glands posterior to the bladder—secrete a sugar-rich fluid that constitutes 60% of the ejaculate.
14. The prostate, surrounding the prostatic urethra, is a group of compound glands embedded in a fibromuscular stroma. Its secretion helps to clot, then to liquefy, the semen. Benign prostatic hyperplasia, which affects many men, arises from the deep glands in the prostate.
15. The bulbourethral glands in the urogenital diaphragm secrete mucus into the urethra before ejaculation to lubricate and neutralize this tube for the passage of semen.

The Penis (pp. 738–739)

16. The penis has a root, a shaft, and a glans covered by foreskin. Its main nerves and vessels lie dorsally. Most of its mass consists of vascular erectile bodies—namely, a corpus spongiosum and two corpora cavernosa. Engorgement of these bodies with blood causes erection.

The Male Perineum (p. 739)

17. In the male, the diamond-shaped perineum contains the scrotum, the root of the penis, and the anus.

Spermatogenesis (pp. 739–742)

18. The three stages of spermatogenesis are (1) formation of spermatocytes, (2) meiosis, and (3) spermiogenesis.
19. In spermiogenesis, round spermatids become tadpole-shaped sperm cells as an acrosome forms, a flagellum grows, the nucleus flattens as its chromatin condenses, and the superfluous cytoplasm is shed.

The Female Reproductive System (pp. 742–755)

20. The female reproductive system produces ova and sex hormones and houses, nourishes, protects, and delivers an infant. It undergoes a menstrual cycle of about 28 days.

The Ovaries (pp. 742–744)

21. The almond-shaped ovaries lie on the lateral walls of the pelvic cavity and are suspended by various mesenteries and ligaments.
22. The mesovarium (mesentery of the ovary) is part of a fold of peritoneum called the broad ligament. (Other parts of the broad ligament are the mesosalpinx and mesometrium.) Contained within the broad ligament are the suspensory ligament of the ovary and its continuation, the round ligament of the uterus.
23. Each ovary is divided into an outer cortex (follicles containing oocytes separated by connective tissue) and an inner medulla (connective tissue containing the main ovarian vessels and nerves). One follicle matures each month, releasing one oocyte from puberty to menopause.

The Uterine Tubes (pp. 744–746)

24. Each uterine tube extends from an ovary to the uterus. Its regions, from lateral to medial, are the infundibulum, ampulla, and isthmus. Fimbriae extending from the infundibulum create currents that help draw an ovulated oocyte into the uterine tube.
25. The wall of the uterine tube contains a muscularis layer and a folded inner mucosa with a simple columnar epithelium. Both the smooth muscle and ciliated epithelial cells help propel the oocyte toward the uterus.

The Uterus (pp. 746–747)

26. The hollow uterus, shaped like an inverted pear, has a fundus, a body, an isthmus, and a cervix. Cervical glands fill the cervical canal with a bacteria-blocking mucus.
27. The uterus is supported by the broad, lateral cervical, and round ligaments. Most support, however, comes from the muscles of the pelvic floor.
28. The uterine wall consists of the outer perimetrium, the muscular myometrium, and a thick mucosa called the endometrium. The myometrium functions to squeeze the baby out during childbirth. The endometrium consists of a functional layer, which sloughs off each month (except in pregnancy), and an underlying basal layer, which replenishes the functional layer.

The Female Menstrual Cycle and Oogenesis (pp. 747–752)

29. The ovarian cycle is responsible for follicle maturation and ovulation. The uterine cycle prepares the uterus for implantation of a fertilized egg.
30. The ovarian cycle has three phases: the follicular phase, ovulation, and the luteal phase. The ovaries of a newborn female contain thousands of primordial follicles, each of which consists of an oocyte surrounded by a layer of flat follicular cells.
31. From puberty to menopause during the follicular phase of each monthly ovarian cycle (days 1–14), 6–12 follicles start maturing. The follicles progress from primordial follicles to primary follicles, to antral follicles, to mature ovarian follicles that are ready for ovulation. Beyond the smallest stages, this progression is stimulated by follicle-stimulating hormone (FSH) from the anterior part of the pituitary gland. Generally, only one follicle per month completes the maturation process.
32. The theca folliculi around a growing follicle cooperates with the follicle itself to produce estrogens from androgens under the stimulatory influence of luteinizing hormone (LH) and FSH. Estrogens stimulate the growth and activity of all female sex organs and signal the proliferative stage of the uterine cycle.

33. Upon stimulation by LH, ovulation occurs at midcycle (day 14), releasing the oocyte from the ovary into the peritoneal cavity.
34. In the luteal phase of the ovarian cycle (days 15–28), the ruptured follicle remaining in the ovary becomes a wavy corpus luteum that secretes progesterone and estrogens. Progesterone functions to maintain the secretory phase of the uterine cycle. If fertilization does not occur, the corpus luteum degenerates in about 2 weeks into a corpus albicans (scar).
35. Oogenesis, the production of female gametes, starts before birth and takes decades to complete. The stem cells (oogonia) appear in the ovarian follicles of the fetus. Primary oocytes stay in meiosis I until ovulation occurs years later, and each secondary oocyte then stays in meiosis II until it is penetrated by a sperm.
36. The uterine cycle has three phases: the menstrual, proliferative, and secretory phases. The first two phases are a shedding and then a rebuilding of endometrium in the 2 weeks before ovulation. The third phase prepares the endometrium to receive an embryo in the 2 weeks after ovulation.

The Vagina (p. 753)

37. The vagina, a highly distensible tube that runs from the uterus to the body's exterior, receives the penis and semen during intercourse and acts as the birth canal.
38. The layers of the vaginal wall are an outer adventitia, a middle muscularis, and an inner mucosa consisting of an elastic lamina propria and a stratified squamous epithelium. The lumen is acidic.
39. The vaginal fornix is a ringlike recess around the tip of the cervix in the superior vagina.

The External Genitalia and Female Perineum (p. 754)

40. The female external genitalia (vulva) include the mons pubis, the labia majora and minora, the clitoris with its erectile bodies, and the vestibule containing the vaginal and urethral orifices. The mucus-secreting greater vestibular glands and the bulbs of the vestibule (erectile bodies) lie just deep to the labia.
41. The central tendon of the perineum lies just posterior to the vaginal orifice and the fourchette.

The Mammary Glands (pp. 754–755)

42. The mammary glands develop from the skin of the embryonic milk lines. Internally, each breast consists of 15–25 lobes (compound alveolar glands) that secrete milk. The lobes, which are subdivided into lobules and alveoli, are separated by adipose tissue and by supportive suspensory ligaments. The full glandular structure of the breast does not develop until the second half of pregnancy. Breast cancers usually arise from the duct system.

PAL Human Cadaver/Reproductive System

Pregnancy and Childbirth (pp. 755–761)

Pregnancy (pp. 755–760)

43. Fertilization usually occurs in the ampulla of a uterine tube. Many sperm must release enzymes from their acrosomes to penetrate the oocyte's zona pellucida. Entry of one sperm into the oocyte prevents the entry of others.

44. Once fertilized, the zygote divides to form a multicellular embryo, which travels to the uterus and implants in the endometrium. As it implants, its trophoblast divides into a cytotrophoblast and an invasive syncytiotrophoblast. Lacunae open in the syncytiotrophoblast and fill with blood from endometrial vessels, forming the first contact between maternal blood and embryonic tissue.
45. The placenta acts as the respiratory, nutritive, and excretory organ of the fetus and produces the hormones of pregnancy. It is formed both from embryonic tissue (chorionic villi) and from maternal tissue (endometrial decidua).
46. The placental exchange barrier consists of the layers of the chorionic villi plus the endothelium of the fetal capillaries inside those villi. Of these layers, the syncytiotrophoblast secretes the placental hormones. No direct mixing of maternal and fetal blood occurs across a healthy placenta.

Childbirth (p. 761)

47. The three stages of labor are the dilation, expulsion, and placental stages.

Disorders of the Reproductive System (pp. 761–763)

48. The most serious cancers of the reproductive organs are prostate cancer and breast cancer.

The Reproductive System Throughout Life (pp. 763–767)

Embryonic Development of the Sex Organs (pp. 763–765)

49. The gonads of both sexes develop in the dorsal lumbar region from the gonadal ridges of intermediate mesoderm. The primordial germ cells migrate to the gonads from the endoderm of the yolk sac. The mesonephric ducts form most of the ducts and glands in males, whereas the paramesonephric ducts form the uterine tubes and uterus of the female.
50. The external genitalia arise from the genital tubercle (penis and clitoris), urethral folds (penile urethra and labia minora), and labio-scrotal swellings (scrotum and labia majora).

Descent of the Gonads (pp. 765–766)

51. The testes form in the dorsal abdomen and descend into the scrotum. The ovaries also descend, but only into the pelvis.

Puberty (p. 766)

52. Puberty is the interval when the reproductive organs mature and become functional. It starts in males with penile and scrotal growth and in females with breast development.

Menopause (pp. 766–767)

53. During menopause, ovarian function declines, and ovulation and menstruation cease.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, see Appendix B.

- Which of the following statements about the female vestibule is correct? (a) The vaginal orifice is the most anterior of the two orifices in the vestibule. (b) The urethra is between the vaginal orifice and the anus. (c) The anus is between the vaginal orifice and the urethra. (d) The urethral orifice is anterior to the vaginal orifice.
- For each of the following hollow organs, choose the correct lining epithelium from the key. (Some linings may be used more than once.)

Key:

- | | |
|----------------------------------|-------------------------------|
| _____ (1) duct of the epididymis | (a) simple squamous |
| _____ (2) uterine tube | (b) simple cuboidal |
| _____ (3) ductus deferens | (c) simple columnar |
| _____ (4) uterus | (d) pseudostratified columnar |
| _____ (5) vagina | (f) stratified squamous |
- Which of the following structures produces the male sex hormones? (a) seminal vesicles, (b) seminiferous tubules, (c) developing follicles of the testes, (d) interstitial cells.
 - The uterine cycle can be divided into three continuous phases. Starting from the first day of the cycle, their order is (a) menstrual, proliferative, secretory; (b) menstrual, secretory, proliferative; (c) secretory, menstrual, proliferative; (d) proliferative, menstrual, secretory; (e) proliferative, secretory, menstrual.
 - Which of the following statements about luteinizing hormone and follicle-stimulating hormone is *false*? They are (a) secreted by the pituitary gland, (b) abbreviated as LH and FSH, (c) hormones with important functions in both males and females, (d) the sex hormones secreted by the gonads.
 - The hormone-secreting layer of the placental barrier is (a) the extraembryonic mesoderm, (b) the lacunae, (c) endothelium, (d) cytotrophoblast, (e) syncytiotrophoblast.
 - The function of the stereocilia in the duct of the epididymis and in the ductus deferens is (a) absorption and secretion, (b) beating forward to move sperm through, (c) initiating ejaculation, (d) beating backward to keep the sperm in these ducts for 20 days.
 - The broad ligament of the uterus in the female pelvis (a) is really a mesentery, (b) consists of the mesovarium and mesosalpinx but not the mesometrium, (c) is the same as the round ligament, (d) is the same as the lateral cervical ligament, (e) b and c.
 - The embryonic paramesonephric duct gives rise to the (a) uterus and uterine tubes, (b) ovary, (c) epididymis and vas deferens, (d) urethra.
 - Which of the following statements about the uterine cervix is *false*? (a) It dilates at the end of the first stage of labor. (b) All of it projects into and lies within the vagina. (c) The cervical glands secrete mucus. (d) It contains the cervical canal.
 - If the uterine tube is a trumpet ("salpinx"), what part of it represents the wide, open end of the trumpet? (a) isthmus, (b) ampulla, (c) infundibulum, (d) flagellum.

- The myometrium is the muscular layer of the uterus, and the endometrium is the (a) serosa, (b) adventitia, (c) submucosa, (d) mucosa.
 - What occurs during the proliferative phase of the uterine cycle? (a) The basal layer of the endometrium thickens. (b) The primary follicles undergo mitosis. (c) The myometrium thickens. (d) The functional layer of the endometrium thickens. (e) The primary spermatocytes form.
 - Which cells in the ovaries secrete hormones? (a) oocytes, (b) zona pellucida, (c) theca and granulosa cells, (d) corpus albicans.
 - Number the ducts through which sperm passes in order beginning with production in the seminiferous tubules (1) and ending with ejaculation out the external urethral orifice (10).
- | |
|-------------------------------------|
| _____ (a) seminiferous tubules |
| _____ (b) epididymis |
| _____ (c) straight tubule |
| _____ (d) ejaculatory duct |
| _____ (e) prostatic urethra |
| _____ (f) rete testis |
| _____ (g) spongy urethra |
| _____ (h) ductus deferens |
| _____ (i) membranous urethra |
| _____ (j) external urethral orifice |
- The hormones that stimulate the ovarian cycle are secreted by the _____; the hormones that stimulate the uterine cycle are secreted by the _____. (a) ovary / uterus, (b) pituitary gland / ovary, (c) follicle cells / functional layer, (d) interstitial cells / placenta, (e) ovary / pituitary gland.
 - Sustentocytes (a) nourish spermatocytes and assist in sperm production, (b) secrete testosterone, (c) secrete fluid that contributes to semen, (d) produce follicle-stimulating hormone.
 - Match the embryonic structures listed in column B with their adult derivatives listed in column A. Some answers may be used more than once.

Column A

- _____ (1) glans penis
 _____ (2) labia minora
 _____ (3) epididymis and ductus deferens
 _____ (4) uterine tubes and uterus
 _____ (5) penile urethra
 _____ (6) labia majora

Column B

- (a) genital tubercle
 (b) mesonephric duct
 (c) urethral folds
 (d) paramesonephric duct
 (e) labioscrotal swellings

Short Answer Essay Questions

- Describe the major structural and functional regions of a sperm cell.
- (a) For a question about the path of the ductus deferens, Ryan's response—that it runs from the scrotum directly up to the penile urethra—was a common error, because the path of this duct is longer and more complex than he thought. Trace the entire path of

- the ductus deferens. (b) To expand on part (a), trace the pathway of an ejaculated sperm from the epididymis all the way into the uterine tube in the female.
21. In menstruation, the functional layer is shed from the endometrium. Explain the hormonal and physical factors responsible for this shedding. (See Figure 25.18.)
 22. (a) Outline the structural changes that a maturing follicle undergoes in the follicular stage of the ovarian cycle. (b) At what time in the ovarian cycle does ovulation occur?
 23. Some anatomy students were saying that a man's bulbourethral glands (and the urethral glands) act like city workers who come around before a parade and clear the street of parked cars. What did they mean by this analogy?
 24. A man swam in a cold lake for an hour and then noticed that his scrotum was shrunken and wrinkled. His first thought was that he had lost his testicles. What had really happened?
 25. Indicate whether the following statement is true or false, and explain your answer: In the placenta, maternal and fetal blood come in direct contact with each other and intermix.
 26. What is the blood-testis barrier, and what is its function?
 27. Tell the difference (if any) between each of the following pairs of sound-alike terms: (a) sperm and spermatocyte, (b) epididymis and duct of epididymis, (c) ovarian ligament and suspensory ligament of the ovary, (d) vulva and vestibule, (e) spermatogenesis and spermiogenesis.
 28. What are the effects of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) on both male and female reproductive structures?
 29. Compare oogenesis with spermatogenesis. How do these processes differ (1) in the number of gametes produced from each primary oocyte or primary spermatocyte and (2) in the period during which mitosis of stem cells occurs?

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Why would a radical mastectomy affect the ability to adduct one's arms (as in doing push-ups)? Would a lumpectomy cause a similar deficit? Why or why not? (Try to remember the main muscle used in doing push-ups.)
2. Based on what you know about the sources of semen, explain the effect of a vasectomy on the volume of the ejaculate.
3. A 68-year-old man who has trouble urinating is given a rectal exam. What condition does he probably have, and what is the purpose of the rectal exam?
4. Gina gave birth to six children. During an examination, the doctor sees her cervix protruding from the vaginal orifice. What is Gina's condition, and what has caused it?
5. Why do doctors often recommend that men not wear tight underwear or tight jeans if they want to father children?
6. Explain how a woman with an ovary removed from one side and a uterine tube removed from the other side can get pregnant (exclude the possibility of in vitro fertilization).
7. In severe cases of endometriosis, endometrial tissue is found within the peritoneum. How can endometrial tissue from the uterus end up in the peritoneum?
8. Name three sets of arteries that must be cauterized during a simple mastectomy (removal of only breast tissue).



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The Metric System

Measurement	Unit and Abbreviation	Metric Equivalent	Metric to English Conversion Factor	English to Metric Conversion Factor
Length	1 kilometer (km)	= 1000 (10^3) meters	1 km = 0.62 mile	1 mile = 1.61 km
	1 meter (m)	= 100 (10^2) centimeters = 1000 millimeters	1 m = 1.09 yards 1 m = 3.28 feet 1 m = 39.37 inches	1 yard = 0.914 m 1 foot = 0.305 m
	1 centimeter (cm)	= 0.01 (10^{-2}) meter	1 cm = 0.394 inch	1 foot = 30.5 cm 1 inch = 2.54 cm
	1 millimeter (mm)	= 0.001 (10^{-3}) meter	1 mm = 0.039 inch	
	1 micrometer (μ m) [formerly micron(μ)]	= 0.000001 (10^{-6}) meter		
	1 nanometer (nm) [formerly millimicron (m μ)]	= 0.000000001 (10^{-9}) meter		
	1 angstrom ($\text{\AA}$)	= 0.0000000001 (10^{-10}) meter		
Area	1 square meter (m^2)	= 10,000 square centimeters	1 m^2 = 1.1960 square yards 1 m^2 = 10.764 square feet	1 square yard = 0.8361 m^2 1 square foot = 0.0929 m^2
	1 square centimeter (cm^2)	= 100 square millimeters	1 cm^2 = 0.155 square inch	1 square inch = 6.4516 cm^2
Mass	1 metric ton (t)	= 1000 kilograms	1 t = 1.103 ton	1 ton = 0.907 t
	1 kilogram (kg)	= 1000 grams	1 kg = 2.205 pounds	1 pound = 0.4536 kg
	1 gram (g)	= 1000 milligrams	1 g = 0.0353 ounce 1 g = 15.432 grains	1 ounce = 28.35 g
	1 milligram (mg)	= 0.001 gram	1 mg = approx. 0.015 grain	
	1 microgram (μ g)	= 0.000001 gram		
Volume (solids)	1 cubic meter (m^3)	= 1,000,000 cubic centimeters	1 m^3 = 1.3080 cubic yards 1 m^3 = 35.315 cubic feet	1 cubic yard = 0.7646 m^3 1 cubic foot = 0.0283 m^3
	1 cubic centimeter (cm^3 or cc)	= 0.000001 cubic meter = 1 milliliter	1 cm^3 = 0.0610 cubic inch	1 cubic inch = 16.387 cm^3
	1 cubic millimeter (mm^3)	= 0.000000001 cubic meter		
Volume (liquids and gases)	1 kiloliter (kl or kL)	= 1000 liters	1 kl = 264.17 gallons	1 gallon = 3.785 L
	1 liter (l or L)	= 1000 milliliters	1 L = 0.264 gallon 1 L = 1.057 quarts	1 quart = 0.946 L
	1 milliliter (ml or mL)	= 0.001 liter = 1 cubic centimeter	1 ml = 0.034 fluid ounce 1 ml = approx. $\frac{1}{4}$ teaspoon 1 ml = approx. 15–16 drops (gtt.)	1 quart = 946 ml 1 pint = 473 ml 1 fluid ounce = 29.57 ml 1 teaspoon = approx. 5 ml
	1 microliter (μ l or μ L)	= 0.000001 liter		
Time	1 second (s)	= $\frac{1}{60}$ minute		
	1 millisecond (ms)	= 0.001 second		
Temperature	Degrees Celsius ($^{\circ}\text{C}$)		$^{\circ}\text{F} = \frac{9}{5}^{\circ}\text{C} + 32$	$^{\circ}\text{C} = \frac{5}{9}^{\circ}\text{F} - 32$

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Answers to Check Your Understanding, Multiple Choice, and Matching Questions

Chapter 1

Check Your Understanding 1. Histology is the microscopic study of tissue structure; radiography is the study of internal body structures from X-ray and other imaging techniques. 2. pathology: study of disease; hepatitis: inflammation of the liver; brachial: arm; leukocyte: white cell; pneumonia: condition of air. 3. A tissue is a group of cells of similar structure with a common function. The four types of tissue are epithelial tissue, a covering or lining tissue; connective tissue, which functions in support and protection; muscle tissue, which produces movement; and nervous tissue, which allows for internal communication by electrical impulses. 4. (a) The urinary system eliminates wastes and regulates water and ion balance. (b) The nervous system is a fast-acting control system. (c) The respiratory system supplies blood with oxygen and removes carbon dioxide. 5. The liver lies inferior to the heart and extends laterally in the epigastric and right hypochondriac regions of the abdomen. 6. The outer tube shows evidence of segmentation. 7. The parietal pleura is the outer layer of serous membrane that lines the pleural cavity. 8. In a tissue stained with H&E, the cell nuclei are colored dark blue to purple. 9. Scanning electron microscopy (SEM) produces three-dimensional images of surface features. 10. (a) Ultrasound is best for examining the gallbladder in the ER. (b) Broken bones are best visualized using conventional X-ray imaging. (c) MRI is best for visualizing joint structure. (d) A CT scan is best for imaging internal organs in a trauma situation.

Review Questions 1. c 2. (1) d; (2) b; (3) a 3. (a) superior; (b) deep; (c) proximal; (d) lateral; (e) medial; (f) posterior; (g) lateral; (h) superior; (i) anterior; (j) superficial 4. (1) d; (2) f; (3) c; (4) j; (5) g; (6) i; (7) a; (8) b; (9) e; (10) h 5. b 6. (1) l; (2) l; (3) o; (4) o; (5) o; (6) l; (7) o 7. (1) D; (2) V; (3) D; (4) V; (5) V 8. (a) 2; (b) 3; (c) 1; (d) 4 9. d 10. (1) c; (2) a; (3) b; (4) d 11. c 12. e

Chapter 2

Check Your Understanding 1. The three regions of the cell are the plasma membrane, the cytoplasm, and the nucleus. 2. The plasma membrane is composed of lipids (phospholipids), sugars (glycolipids), and proteins. 3. Water enters and leaves the cell via osmosis. 4. Exocytosis carries large macromolecules out of the cell. 5. Ribosomes and rough ER produce proteins; the Golgi apparatus packages proteins. 6. The mitochondria produce energy for cellular activity. 7. A cell that specialized in phagocytosis would contain numerous lysosomes. 8. The intermediate filaments resist tension. 9. The nucleolus produces ribosomal RNA and assembles the ribosomal subunits. 10. Rough endoplasmic reticulum is

continuous with the nuclear envelope. 11. Extended chromatin is thin strings of chromatin that appear as beads (histones) on a string (DNA) in TEM. Extended chromatin is found in active regions of DNA where transcription is occurring. Condensed chromatin is thick, tightly coiled chromatin that is found in inactive regions of DNA. 12. The cell spends most of its life in interphase. 13. Anaphase = "apart"; the chromosomes move toward opposite poles of the cell during anaphase. Meta = "between, transition"; during metaphase, the chromosomes align in the midline of the cell. Telo = "the end"; in telophase, the nuclei of daughter cells reassemble, cytokinesis continues, cell division ends. 14. Muscle cells have abundant actin and myosin microfilaments. 15. Cells that produce and secrete hormones contain abundant rough ER, mitochondria, and secretory granules. 16. According to the mitochondrial theory of aging, reducing caloric intake can increase life span.

Review Questions 1. a 2. a 3. b 4. a 5. (a) Golgi apparatus (b) rough ER (c) condensed (d) smooth (e) nucleosome (f) microtubules (g) mitochondrion (h) mitochondrion (i) rough ER 6. d 7. b 8. a 9. (a) metaphase (b) prophase (c) telophase (d) prophase (e) anaphase 10. (a) microtubules (b) intermediate filaments (c) microtubules (d) actin microfilaments (e) intermediate filaments (f) microtubules (g) actin microfilaments 11. (1) b; (2) g; (3) c or b; (4) d; (5) e; (6) f; (7) a 12. b

Chapter 3

Check Your Understanding 1. The basic vertebrate body plan is established during the embryonic period. 2. The digestive tract (stomach, intestines) forms from the inner tube, as do the liver, pancreas, and gallbladder. 3. The kidneys are located posterior (or dorsal) to the peritoneal cavity. 4. During gastrulation, cells from the epiblast invaginate (move inward) and form three separate germ layers. This process occurs during the third week of development. 5. The notochord induces the formation of the neural tube. 6. Somites, from the paraxial mesoderm, and intermediate mesoderm cluster into segments along the body axis. 7. Ectoderm forms the outer covering of the embryo. 8. Endoderm forms the inner lining of the inner tube. 9. The sclerotome forms the vertebra and ribs. 10. Splanchnic lateral plate mesoderm forms the connective tissues, muscle tissues, visceral serosa of the respiratory and digestive tubes, and the heart and blood vessels. 11. Lungs are not fully developed until the end of the seventh month in utero. Babies born prior to this time commonly experience respiratory distress.

Review Questions 1. (1) a; (2) b; (3) b; (4) a 2. b 3. b 4. c 5. (1) c; (2) f; (3) i; (4) h; (5) a; (6) d; (7) b; (8) g; (9) e 6. (1) c; (2) g; (3) d; (4) e; (5) f; (6) a; (7) b 7. c 8. d 9. a, d 10. e 11. a 12. a 13. d 14. a 15. c 16. d

Chapter 4

Check Your Understanding 1. The apical layer of the epithelium abuts the white space in each photograph (a–h). 2. Larger-sized cells allow for more room for cellular machinery necessary for producing cellular secretions (ER, ribosomes, Golgi apparatus, mitochondria). Cuboidal epithelium is found in kidney tubules, glands, and the ovary surface. 3. Diffusion is a distant-dependent process; columnar epithelium is too thick for efficient diffusion. Simple squamous epithelium is found in these locations. 4. Goblet cells are unicellular exocrine glands that secrete mucin (mucus). 5. endocrine 6. Simple exocrine glands have unbranched ducts; the ducts of compound glands are branched. 7. Microvilli are short extensions of the plasma membrane with a core of actin microfilaments that extend into the cytoskeleton. They increase the surface area of the plasma membrane. A cilium is a long extension of the plasma membrane composed of a core of microtubules arranged in pairs linked by motor proteins and anchored to a centriole at its base. The bending of a cilium produces movement of the fluid at the epithelial surface. 8. Intermediate filaments extend across the cell and anchor at desmosomes on the opposite side. Linker proteins from the desmosomes link to adjacent cells. 9. Other tissues that contain gap junctions are embryonic tissues, connective tissues, cardiac muscle, and smooth muscle. 10. Epithelial tissues contain lots of cells of similar type closely packed together into sheets with little extracellular matrix. Connective tissues contain fewer cells of various types separated from each other by extensive extracellular material. 11. The matrix of a connective tissue is composed of both ground substance and fibers. The ground substance is commonly a gel-like material that functions to hold fluid. 12. Collagen fibers in connective tissues resist tension; the ground substance resists compression; and the elastic fibers allow for recoil. 13. The fibers of loose connective tissues are separated from each other by ground substance. In dense connective tissue, the fibers are closely packed together. 14. Ligaments and tendons are formed from dense regular connective tissue. The hypodermis is composed of adipose and loose areolar connective tissue. The connective tissue that underlies epithelia is loose areolar connective tissue. Reticular connective tissues contribute to the structure of lymph nodes. 15. Collagen fibers are found in loose areolar, adipose, dense regular, and irregular connective tissues; hyaline cartilage elastic cartilage, and fibrocartilage; and bone. 16. Cells are located in lacunae in both cartilage and bone tissues. 17. In cartilage, compressive forces are resisted by the gel-like ground substance. 18. Most obvious reason that the tissue in Figure 4.10c is not an epithelial tissue is that it does not have an apical and basal region.

19. Neurons function to transmit electrical impulses. 20. Skeletal muscle and cardiac muscle tissues are striated. (Do NOT confuse *striated* with *stratified*. *Stratified*, which means “layered,” is used in reference to epithelium; *striated*, which means “striped,” refers to muscle tissue.) 21. Epithelia and some connective tissues (bone, areolar connective tissue, dense irregular connective tissue, blood) regenerate easily. Cardiac muscle and nervous tissue in brain and spinal cord do not regenerate. 22. Scar tissue is located in the underlying connective tissue. 23. Increased blood flow to an infected tissue and increased fluid leakage from capillaries serving the infected area cause the heat and swelling associated with infection. 24. Epithelia forms from all three embryonic germ layers: ectoderm, mesoderm, and endoderm. 25. Cell division in cancerous cells is uncontrolled, and cells expand beyond their normal tissue boundaries.

Review Questions 1. (1) a; (2) c; (3) d; (4) b; (5) b 2. c and e 3. (1) b; (2) f; (3) a; (4) d; (5) g 4. b 5. a 6. (a) cilia; (b) microvilli; (c) desmosome; (d) tight junction; (e) basement membrane 7. (1) e; (2) a; (3) b; (4) c; (5) d 8. (1) a; (2) a,b,c; (3) a; (4) c; (5) a 9. d 10. c 11. b 12. b 13. (a) mesoderm; (b) mesoderm; (c) ectoderm

Chapter 5

Check Your Understanding 1. The word root *epi* means “over” or “above”; *hypo* means “below”; and *derm* means “skin.” 2. The five main functions of skin are protection, body temperature regulation, excretion, production of vitamin D, and sensory reception. 3. The stratum basale, stratum spinosum, and stratum granulosum are the epidermal layers containing living cells. 4. Cells in the epidermis function in protection, production of vitamin D, and sensory reception. 5. Thick skin contains an additional layer, the stratum lucidum, and has a much thicker stratum corneum. 6. Dermal blood vessels dilate to release heat when the body is warm, and they constrict to prevent the loss of heat when the body is cold. 7. (a) The papillary layer of the dermis is composed of loose areolar connective tissue. (b) The reticular layer is dense irregular connective tissue. (c) The hypodermis contains both loose areolar and adipose connective tissue. 8. Fibroblasts in the dermis produce the collagen and elastic fibers of the dermis. These fibers give the skin strength, resilience, and recoil properties; the macrophages, mast cells, and white blood cells function to fight infections. 9. The large variation in skin color in humans is due to variation in the type and amount of melanin in the epidermal layer. 10. A dark-skinned individual in northern latitudes would have concerns about vitamin D production. Because there is less sunlight, particularly in the winter months, dark skin produces less vitamin D than light skin. 11. The keratin in hair and nails is a hard keratin: it is tougher and more durable, and its cells do not flake off. 12. Hair and the hair follicle form from the epidermal layer. 13. The cells of the medulla are deepest layer of hair cells, the next layer of cells is the cortex, and the outermost layer is the cuticle. 14. Chemotherapy stops the cell division of the cells in the hair matrix, causing hair to fall out, but it does not destroy the hair follicles. A severe burn, however, destroys hair follicles; thus, hair cannot regrow. 15. Apocrine sweat glands do not cause acne. Acne is caused by sebaceous glands, which also become active at adolescence. 16. Eccrine sweat glands, like most glands, are formed from cuboidal epithelium. In some portions of the micrograph, this epithelium appears stratified because of the section. 17. Eccrine glands function in temperature regulation (sweat causes evaporative cooling)

and excretion (sweat contains metabolic wastes, salts, and water). 18. Second-degree burns cause blisters. 19. The life-threatening concerns associated with third-degree burns are fluid loss and the resulting circulatory shock, followed by risk of infection. Fluid loss is treated with intravenous fluids to maintain blood volume. To prevent infection, the damaged area is covered with either skin grafts or artificial skin, and intravenous antibiotics are given. 20. Basal cell carcinoma is the most common type of skin cancer. Melanomas are the skin cancers that can be fatal. 21. Appendages of the skin develop from ectoderm. The hypodermis develops from mesoderm. 22. UV radiation degrades the collagen fibers and other components of the dermis.

Review Questions 1. c 2. (1) e; (2) b or d; (3) a; (4) c; (5) d 3. d 4. d 5. b 6. a 7. c 8. b 9. d 10. d 11. (1) b; (2) a; (3) a; (4) b; (5) d 12. a 13. (1) e; (2) d; (3) f; (4) b,g; (5) a; (6) g; (7) c 14. c 15. (1) d; (2) a; (3) e; (4) c; (5) d; (6) d; (7) d

Chapter 6

Check Your Understanding 1. The matrix of the three types of cartilage differs in the amount and type of fibers found in each. Hyaline cartilage has small collagen fibrils; elastic cartilage has both collagen and elastic fibers; and fibrocartilage contains thick bundles of collagen. 2. Hyaline cartilage is most abundant. It is located in articular cartilages, respiratory passageways, costal cartilages of ribs, the embryonic skeleton, and the cartilages of the nose. 3. Chondroblasts in the perichondrium produce new cartilage by appositional growth. 4. Collagen fibers contribute to the strength and flexibility of bone, and the mineralized ground substance makes bone hard. 5. Calcium and phosphate are stored in bone. These minerals are released by the action of osteoclasts. 6. Osteoblasts secrete new bone matrix. Osteocytes are surrounded by bony matrix and function to keep the matrix healthy. 7. Periosteum covers the external surfaces of bone (except for the articular areas); endosteum covers the internal surfaces of bone (including the central and perforating canals). Both membranes contain osteoblasts and osteoclasts. 8. In a flat bone, compact bone is located on the external surfaces, and spongy bone is located internally. 9. A condyle is a joint surface. A tubercle is an attachment site for muscle or ligament. A foramen is a hole in the bone that acts as a passageway for vessels or nerves. 10. The central canal is in the middle of an osteon; the perforating canals connect osteons; canaliculi are small connections between lacunae that link adjacent osteocytes. 11. Oxygen and nutrients diffuse through the spaces in the matrix, the canaliculi and lacunae of the inner lamellae, to reach the cells in the outermost lamella. 12. A trabecula is a “beam” of bone composed of several lamellae and associated osteocytes. The bone tissue in a trabecula is not aligned in concentric rings around a central canal, as it is in an osteon. 13. Most bones of the skull, except for parts of the base of the skull and the clavicle, are membrane bones. 14. In a 6-month-old fetus, only the diaphysis of the long bone is ossified. 15. The thickness of the epiphyseal plate does not change during childhood. As the long bone grows, bone is added to the diaphyseal end of the epiphyseal plate. 16. Exercise stimulates bone deposition. Mechanical stress on the bone stimulates osteoblasts to produce additional bone matrix. 17. Remodeling of the bony callus following a fracture makes the repaired area resemble the original unbroken bone. 18. Comminuted and compression fractures are common in older individuals. 19. Osteomalacia and rickets result from inadequate mineralization of bone. 20. Activity of

osteoclasts should be targeted to slow bone loss. 21. Development of osteoporosis is best prevented during the bone-building years of adolescence and early adulthood. 22. Bones begin to ossify by week 8 of embryonic development. Bone mass starts to decline around age 40. 23. Estrogens aid in maintaining bone density. Estrogen decline in postmenopausal women increases their risk of bone loss.

Review Questions 1. e 2. a 3. e 4. (1) a; (2) b; (3) a; (4) c; (5) a 5. (1) T; (2) F; (3) T; (4) F; (5) F; (6) T; (7) T 6. b 7. c 8. (1) a; (2) b; (3) c; (4) a; (5) b; (6) a 9. d 10. c 11. (a) 3; (b) 2; (c) 4; (d) 1; (e) 5; (f) 6 12. b 13. c 14. b 15. b 16. a 17. a 18. (1) b,d; (2) a,d; (3) b; (4) c; (5) a,c

Chapter 7

Check Your Understanding 1. The frontal, ethmoid, and sphenoid bones form the anterior cranial fossa. 2. The crista galli is on the ethmoid bone; the mastoid process is on the temporal bone; the nuchal line is on the occipital bone; the sella turcica is on the sphenoid bone; the supraorbital foramen is on the frontal bone; the zygomatic process is on the temporal bone. 3. The four bones that articulate with the left parietal bone are the right parietal bone via the sagittal suture; the frontal bone via the coronal suture; the left temporal bone via the squamous suture; and the occipital bone via the lambdoid suture. 4. The bones that articulate with the maxilla are the zygomatic, vomer, palatine, nasal, lacrimal, ethmoid, and inferior nasal concha. 5. The hard palate is formed from the horizontal plates of the palatine bones and palatine processes of the maxillae. 6. The alveolar margins are the superior margin of the mandible and the inferior margin of the maxilla that contain the teeth in the alveoli (sockets). 7. Nasal conchae are formed from the ethmoid bone (superior and middle) and the inferior nasal concha. These conchae create turbulence in the incoming air and function to warm, moisten, and filter the air. 8. Cranial bones contributing to the orbit are the frontal, sphenoid, and ethmoid bones; the facial bones that contribute to the orbit are the lacrimal, maxillary, zygomatic, and palatine bones. 9. Ethmoidal air cells and maxillary sinuses are located in the lateral walls of the nasal cavity. All sinuses are lined with a mucous membrane. 10. The nucleus pulposus, the inner core of the intervertebral disc, expands under compression. The outer rings of fibrocartilage, the annulus fibrosus, function to resist twisting forces. 11. The cervical curvature develops at 3 months, as the infant begins to hold up his head; the lumbar curvature develops around 1 year, when the baby begins to walk. 12. The annulus fibrosus is thinnest posteriorly, but the posterior longitudinal ligaments prevent direct posterior herniation; thus, most herniations occur in the posterolateral direction. 13. The superior articular process of a vertebra articulates with the inferior articular process of the vertebra just superior. 14. All cervical vertebrae have a transverse foramen. This is the most distinctive feature. Other possible answers are listed in Table 7.2. 15. Thoracic vertebra T₁₂ has costal facets on its vertebral body; lumbar vertebra L₁ does not. 16. The fused spinous processes of the sacral vertebrae form the median sacral crest. 17. The sternal angle is the junction between the manubrium and the body of the sternum. Rib 2 articulates here. 18. The head of the rib articulates with the superior and inferior costal facets of the thoracic vertebra. The tubercle of the rib articulates with the transverse costal facet. 19. The frontal bone and mandible form as two individual bones that fuse during childhood. 20. Age-related degenerative bone loss can cause kyphosis.

Review Questions 1. (1) b,g; (2) h; (3) d; (4) d,f; (5) e; (6) c; (7) a,b,d,h; (8) i 2. c 3. c 4. a 5. a 6. (1) a; (2) c; (3) f; (4) b; (5) d; (6) e; (7) c; (8) d; (9) f; (10) e 7. (1) e; (2) d; (3) b; (4) a; (5) c

Chapter 8

Check Your Understanding 1. The acromion of the scapula articulates with the clavicle. 2. The only bony attachment between the pectoral girdle and the axial skeleton is the clavicle joining with the sternum and rib 1. 3. The three fossae of the scapula are the supraspinous fossa, "above" the scapula spine; the infraspinous fossa, "below" the scapula spine; and the subscapular fossa, "beneath" the scapula on its anterior surface. 4. The radius is on the lateral side of the forearm. 5. The capitulum is on the humerus, and it articulates with the head of the radius. The trochlear notch is on the ulna, and it articulates with the trochlea of the humerus. The head of the ulna is on the ulna, and it articulates with the ulna notch of the radius. The radial notch is on the ulna, and it articulates with the head of the radius. 6. The anatomical neck of the humerus is just inferior to the head; it is the area where the diaphysis joins with the proximal epiphysis. The surgical neck, the most frequently fractured region of the humerus, is inferior to the greater and lesser tubercles. 7. The metacarpals are located in the palm of the hand. 8. The pubis is the most anterior bone of the pelvic girdle. 9. When you sit, the ischial tuberosities carry your weight. 10. When your hands are on your hips, your hands are resting on the iliac crests. 11. The pubic arch is greater in females than in males; the greater sciatic notch is wider and more shallow in females than in males; and the sacrum is wider, shorter, and more curved in females. 12. The acetabulum of the hip bone articulates with the head of the femur. 13. The bony bumps on either side of your ankle are formed by the medial malleolus of the tibia and the lateral malleolus of the fibula. 14. The lateral malleolus is on the fibula; the linea aspera is on the femur; the lesser trochanter is on the femur; the fibular notch is on the tibia; the talar shelf is on the calcaneus; and the tibial tuberosity is on the tibia. 15. The anterior portion of the talus is the keystone of the medial longitudinal arch. The arches distribute weight anteriorly to the heads of the metatarsals (the "ball of the foot") and posteriorly to the calcaneus (heel). 16. The skeleton in males becomes more robust at puberty. In females, the pelvis broadens. 17. The three bones of the hip fuse together during childhood at the acetabulum. Splinting holds the femoral head in place so the acetabulum and surrounding ligaments can form normally.

Review Questions 1. (1) g; (2) f; (3) b; (4) a; (5) b; (6) c; (7) d; (8) e 2. (1) b; (2) c; (3) e; (4) a; (5) h; (6) e (7) f 3. e 4. b 5. d 6. a 7. c,d, (f) 8. c 9. b 10. c

Chapter 9

Check Your Understanding 1. A synarthrosis is an immovable joint. This is a functional joint classification. A syndesmosis is a fibrous joint where the adjoining bones are connected exclusively by ligaments. A synchondrosis is a cartilaginous joint where hyaline cartilage unites adjoining bones. Both syndesmosis and synchondrosis are considered structural classifications. 2. A symphysis joint contains both hyaline cartilage, which covers the articular joint surfaces, and fibrocartilage, which unites adjoining bones. 3. The six basic features of synovial joints are (1) articular cartilage, (2) a joint cavity, (3) an articular capsule, (4) synovial fluid, (5) reinforcing ligaments, and (6) nerves and vessels. 4. An articular disc is composed of fibrocartilage,

and it is located within the joint cavity. Articular cartilage is composed of hyaline cartilage and covers the adjoining surfaces of all synovial joints. 5. Synovial fluid nourishes the cells of the articular cartilage and lubricates the joint surfaces. 6. (a) The movements that occur at the elbow are flexion and extension. (b) The hip allows flexion/extension, abduction/adduction, medial and lateral rotation, and circumduction. (c) Dorsiflexion and plantar flexion occur at the ankle. (d) Rotation occurs at the atlantoaxial joint. (e) The metacarpophalangeal joint can produce flexion/extension, abduction/adduction, and circumduction. 7. (a) The elbow is a uniaxial hinge joint. (b) The hip is a multiaxial ball-and-socket joint. (c) The ankle is a uniaxial hinge joint. (d) The atlantoaxial joint is a uniaxial pivot joint. (e) The metacarpophalangeal joint is a biaxial condyloid joint. 8. Pronation is medial rotation of the forearm such that the palm faces posteriorly; supination is lateral rotation of the forearm such that the palm faces anteriorly. This movement occurs at the proximal and distal radioulnar joints. 9. The articular disc in the sternoclavicular and the temporomandibular joints divide each joint cavity and enable multiple complex movements of each joint. 10. The knee also contains an articular disc. 11. The elbow is the most stable, and the shoulder is the least stable. 12. The muscle tendons that cross the shoulder contribute most to its stability. 13. The ulna forms part of the elbow. The radius forms part of the wrist joint. 14. The intracapsular ligament of the hip is the ligament of the head of the femur. The intracapsular ligaments of the knee are the anterior and posterior cruciate ligaments. 15. Forceful inversion of the ankle can sprain the lateral ligament. 16. The medial and lateral menisci of the knee aid in joint stability, as do the extensive capsular, extracapsular, and intracapsular ligaments. 17. (a) Gouty arthritis is caused by crystallization of uric acid in the synovial membranes. (b) Osteoarthritis is the erosion of the articular cartilage. (c) Rheumatoid arthritis is an autoimmune response causing inflammation of the synovial membrane. 18. A sprain or subluxation stretches the joint capsule and surrounding ligaments and makes the joint more susceptible to repeat injury. 19. Synovial joints form by week 8 of fetal development.

Review Questions 1. (1) a,b; (2) a; (3) a; (4) a; (5) b; (6) c; (7) c; (8) a,b; (9) c 2. e 3. c 4. e 5. a 6. (1) a,c; (2) b,d; (3) c; (4) c; (5) b,d 7. (1) g; (2) e; (3) a; (4) a,b,g; (5) d; (6) g; (7) h; (8) e,c; (9) g 8. (1) c; (2) e; (3) b; (4) d; (5) d; (6) d; (7) c; (8) a; (9) a; (10) a

Chapter 10

Check Your Understanding 1. All muscle tissue contains the myofilaments actin and myosin, which generate contractile forces; the plasma membrane is called a sarcolemma; and the cytoplasm is called sarcoplasm. The functional characteristics of muscle tissue are (1) contractility, (2) excitability, (3) extensibility, and (4) elasticity. 2. Cardiac muscle and skeletal muscle are striated. Cardiac muscle and smooth muscle are called visceral muscle, because they occur in the visceral organs and are not voluntarily controlled. 3. Perimysium is the fibrous connective tissue that surrounds a fascicle. 4. The origin of a muscle is the attachment site of the muscle that does not move when the muscle contracts. The insertion is the attachment site on the bone that does move when the muscle contracts. In the limbs, conventionally, the origin is the more proximal attachment, and the insertion is located distally. 5. Smallest to largest: myofilament, sarcomere, myofibril, muscle fiber. Myofilaments are composed of the contractile proteins actin and myosin. In striated muscle, the myofilaments are arranged into sarco-

meres, the smallest contractile unit in striated muscle. A myofibril is an organelle within a muscle cell made up of repeating sarcomeres. A muscle fiber is a muscle cell. 6. The thick (myosin) myofilaments are limited to the A band. 7. The terminal cistern stores Ca^{2+} . The T tubules carry the stimulus to contract from the surface sarcolemma to the deeper regions of the muscle fiber, initiating the release of Ca^{2+} from the terminal cistern. 8. The myosin heads must attach to the overlapping thin filament to generate a contractile force. If there is no overlap, the myosin heads have nothing to attach to. 9. The length of the I band shortens during muscle contraction.

10. The neuromuscular junction is the connection between a single axon terminal and a muscle fiber. A motor unit is a single motor neuron and all of the muscle fibers it innervates. 11. Usain Bolt has a predominance of fast glycolytic muscle fibers in his lower limbs. 12. Muscle tissue from an individual with this Duchenne muscular dystrophy has muscle fibers of irregular size, and in many regions the muscle fibers are replaced with fat and connective tissue. 13. Skeletal muscle fibers form from the fusion of multiple embryonic cells; thus, they are multinucleated. 14. Weight-training exercise increases the size of muscle fibers and thus helps maintain muscle strength in older individuals.

Review Questions 1. c 2. b 3. (1) thin; (2) thick; (3) thick; (4) thin; (5) thick; (6) thin 4. (1) yes; (2) no; (3) yes; (4) no 5. (1) d; (2) a; (3) b; (4) e; (5) c 6. c 7. c 8. a 9. (1) b; (2) a; (3) c; (4) c; (5) b; (6) a; (7) a,c (8) c; (9) c; (10) a,b,c

Chapter 11

Check Your Understanding 1. The fascicles are arranged in parallel in Figure 11.2a. 2. The power of a muscle depends on the total number of muscle fibers. Pennate muscles pack more muscle fibers into a unit area than parallel muscles; thus, they are able to generate greater force. 3. Second class levers always operate at a mechanical advantage. First class levers operate at a mechanical advantage when the length of the effort arm is longer than the length of the load arm. 4. The fulcrum of a skeletal/muscular lever system is the joint. 5. Levers that operate at a mechanical disadvantage allow for greater speed and larger distance of movement for a given muscular effort. 6. (a) The muscles that move the thigh are limb muscles. (b) The abdominal muscles are axial muscles. (c) The chewing muscles are pharyngeal arch muscles. 7. Muscles that develop on the dorsal side of the limb are extensor muscles. 8. The biceps brachii and brachialis function as synergists. 9. A thigh abductor crosses the hip on the lateral side of the joint. The antagonist muscle produces adduction. 10. Muscles that cross on the posterior side of a joint generally produce extension. 11. The biceps brachii and brachialis are located in the anterior compartment of the arm. Their antagonist muscle group, the triceps brachii, are located in the posterior compartment of the arm. 12. Muscles in the posterior compartment of the thigh extend the thigh and flex the knee. The quadriceps femoris group functions as an antagonist to these muscles. 13. The gastrocnemius and soleus act in synergy as prime movers for plantar flexion. 14. (a) *Latissimus dorsi* means "wide back," an excellent description of this superficial back muscle. (b) *Sternocleidomastoid* indicates that the origin of this muscle is at the sternum and clavicle and that its insertion is on the mastoid process of the temporal bone. (c) *Serratus anterior* refers to the saw-like appearance of this muscle, much like a serrated knife, and its location on the anterior/lateral thoracic wall. (d) The adductor magnus is the large adductor muscle of the thigh. 15. The diaphragm is the most important

muscle for inspiration. The intercostal muscles, pectoralis minor, the scalenes, and sternocleidomastoid aid in forceful inspiration. The abdominal muscles aid in forceful expiration. **16.** The six movements of the shoulder joint are flexion, extension, abduction, adduction, medial rotation, and lateral rotation. The muscles involved in these movements are described in Table 11.11, p. 000. **17.** The prime mover of dorsiflexion is the tibialis anterior. Dorsiflexion of the foot keeps the toes from dragging during the recovery phase of walking. **18.** The lesser gluteals shift the trunk from side to side during walking to keep the body upright and to keep the center of gravity over the limb that is on the ground. Without their action, the trunk would fall over toward the unsupported side when the limb is in the swing phase of gait. **19.** The linea alba runs down the anterior abdominal wall from the xiphoid process to the symphysis pubis. The external and internal oblique and the transversus abdominis muscles insert into the linea alba. **20.** The triangle of auscultation is bounded by the trapezius medially, the latissimus dorsi inferiorly, and the medial border of the scapula laterally. The area is used to listen for lung sounds. **21.** Intramuscular injections can be given in the deltoid, about 5 cm inferior to the rounded superior part of the shoulder; the gluteus medius, 5 cm superior from the midpoint between the posterior superior iliac spine and the greater trochanter; or midway down the vastus lateralis on the lateral thigh. **22.** (a) The supracristal line is in the lumbar region. (b) The linea semilunaris is in the abdomen. (c) The cubital fossa is on the anterior side of the elbow. (d) The median bicipital furrow is on the medial side of the arm. **23.** The boundaries of the posterior triangle of the neck are the sternocleidomastoid muscle anteriorly, the trapezius posteriorly, and the clavicle inferiorly. The carotid pulse is located in the anterior triangle just anterior to the sternocleidomastoid and superior to the level of the larynx. **24.** In most individuals, the tendons of palmaris longus and flexor carpi radialis are apparent in the distal forearm when the person makes a fist.

Review Questions 1. d 2. c 3. (1) c; (2) b; (3) e; (4) a; (5) d 4. e 5. c 6. d 7. c 8. b 9. b 10. a 11. d 12. b 13. b

Chapter 12

Check Your Understanding 1. Afferent signals carry sensory information toward the CNS. 2. The visceral motor (autonomic) division of the peripheral nervous system regulates contraction of cardiac muscle. 3. (a) Pain from a pulled muscle is somatic sensory. (b) Nausea is visceral sensory. (c) Taste is a special visceral sensory sensation. 4. The neuronal cell processes that receive stimuli are the dendrites. 5. When an electrical impulse in the presynaptic neuron reaches the axon terminal, it stimulates the release of chemical neurotransmitters from this neuron. These neurotransmitters diffuse across the synaptic cleft, bind to receptor sites on the postsynaptic neuron (usually on the dendrite or cell body), and stimulate an electrical response in the postsynaptic neuron. In this way, the electrical signal is passed, via a chemical messenger, from one neuron to another. 6. Most sensory neurons are unipolar (pseudounipolar) neurons. 7. Multipolar neurons are the most abundant type of neuron. Motor neurons of the PNS are multipolar neurons. 8. Oligodendrocytes produce myelin in the CNS, and Schwann cells produce myelin in the PNS. 9. Astrocytes are common in regions where synapse occurs because they regulate ionic and neurotransmitter levels in neural tissue. 10. Schwann cells do cover unmyelinated axons in the PNS; however, these axons are not wrapped by concentric layers of the Schwann cell. Numerous unmyelinated

axons are embedded in a single Schwann cell (see Figure 12.7). 11. The perineurium wraps a bundle of nerve fibers (axons) into a fascicle. 12. Synapses in the CNS always occur in the gray matter. 13. The white matter of the CNS appears white because the majority of the nerve fibers in these regions are myelinated. 14. The integration center occurs in the gray matter of the CNS at the synapse between the sensory neuron and motor neuron. 15. The sensory impulse must be carried to the brain for processing the conscious sensation of pain. This processing takes more time than is required for processing the simple withdrawal reflex. 16. A converging circuit contains multiple presynaptic neurons synapsing on a single postsynaptic neuron. 17. After a peripheral injury, axons in the PNS can regrow within regeneration tubes formed by surviving Schwann cells. In the CNS, neuroglia do not guide regrowing axons and, in fact, secrete inhibitory chemicals that block neuronal regrowth. 18. Myelin insulates nerve signals and increases the speed of impulse conduction. Loss of myelin in the CNS, as occurs with MS, interferes with the conduction of nerve signals. All of the symptoms described for MS indicate disruption of neural processing (balance disorders, muscle weakness, vision disturbance). 19. The neuroblasts of the basal plate form motor neurons. 20. Sensory neurons develop from neural crest tissue, which is located outside the developing neural tube.

Review Questions 1. b 2. (1) d; (2) b; (3) f; (4) c; (5) a; (6) a 3. b 4. (1) SS; (2) VS; (3) VM; (4) SM; (5) VS; (6) SS; (7) SM 5. b 6. b 7. a 8. c 9. d 10. (1) c; (2) b; (3) a 11. b 12. c 13. d 14. 2, 1, 3

Chapter 13

Check Your Understanding 1. Lumbar spinal nerves L₃–L₅ and sacral spinal nerves S₁–S₅ pass through the vertebral foramen of lumbar vertebra L₅. 2. White matter provides the two-way conduction pathway between the brain and spinal cord. 3. Somatic motor neurons to the muscles of the upper limb are located in the ventral horn of the lower cervical segments. Paralysis of these muscles would result from damage to this region of the spinal cord. 4. Cerebrospinal fluid is located in the subarachnoid space, which is located deep to the arachnoid mater and superficial to the pia mater. 5. The telencephalon forms the cerebrum, and the mesencephalon forms the midbrain. 6. Brain nuclei are clusters of neuronal cell bodies that form portions of the gray matter of the CNS. 7. The third ventricle is connected to the fourth ventricle through the cerebral aqueduct, located in the midbrain. 8. (a) The pyramids of the medulla are white fiber tracts connecting the cerebrum with the spinal cord. (b) The vestibular and cochlear nuclei are involved with innervation of the head. They receive sensory impulses from the cranial nerves that innervate the inner ear. (c) The cerebral peduncles are white fiber tracts in the midbrain connecting the cerebrum with the brain stem. (d) The periaqueductal gray matter is involved with the autonomic behaviors associated with the fight-or-flight response and mediates the response to visceral pain. Two cranial nerve nuclei are also located here. (e) The trigeminal nuclei are involved with sensory innervation of the face and motor innervation of the chewing muscles. 9. The pyramids (a) and the vestibular and cochlear nuclei (b) are located in the medulla oblongata. The cerebral peduncles (c) and the periaqueductal gray matter (d) are in the midbrain. The trigeminal nuclei (e) are in the pons. 10. The corpora quadrigemina are four brain nuclei located at the roof of the midbrain involved with auditory (inferior colliculi) and visual (superior colliculi) reflexes. 11. The vermis connects the two cerebellar hemispheres. 12. The flocculonodular lobe receives sensory information

from the vestibular nuclei about equilibrium. 13. The superior cerebellar peduncles connect the midbrain to the cerebellum; the middle cerebellar peduncles connect to the pons; and the inferior cerebellar peduncles extend from the medulla to the cerebellum. 14. Axonal fibers from the thalamic nuclei extend to the cerebral cortex. 15. The hypothalamus is the main visceral control center. Visceral control refers to regulation of the activities of the visceral organs, including autonomic motor activity and endocrine functions. 16. The primary sensory cortex enables conscious awareness of a sensation. The sensory association area places the sensory stimulus into a context that gives meaning to the stimulus. 17. The premotor cortex plans complex movements. The primary motor cortex signals the execution of these movements. 18. Contralateral ("opposite side") projection refers to the crossing over of nerve fibers to the opposite side of the body, such that the right side of the body is controlled or perceived by the left side of the brain. 19. The visual cortex and association area are located in the occipital lobe. Visual deficits would result from injury to this region. 20. Projection fibers connect the cerebral cortex to more caudal regions of the CNS. 21. The caudate nucleus is located just lateral to the lateral ventricles. 22. The reticular nuclei receive input from all major ascending sensory tracts. These nuclei project to the cerebrum (via relays through the thalamus), thus maintaining alertness. 23. The amygdala is the brain nucleus for processing and responding to fear. 24. The falx cerebri lies in the longitudinal fissure. 25. Cerebrospinal fluid (CSF) is produced by the choroid plexuses in the roof of the brain ventricles. CSF returns to the blood vascular system through the arachnoid villi, which empty into the dural sinuses. 26. Discriminative touch sensations are carried on the dorsal column pathways (fasciculus cuneatus and fasciculus gracilis). 27. The dorsal column and spinothalamic pathways pass through the thalamus. The spinocerebellar pathway does not. 28. The pyramidal pathways (lateral and ventral corticospinal) originate from the primary motor cortex. 29. The ascending spinocerebellar tract and some fibers of the reticulospinal tract do not cross over. 30. Most of the ascending and descending pathways project contralaterally. 31. The thalamus and the somatosensory cortex are active in a newborn. The frontal lobe (the location of rational thought) is not fully developed until early adulthood.

Review Questions 1. (1) c; (2) f; (3) e; (4) g; (5) b; (6) e; (7) i; (8) a; (9) g; (10) h; (11) d 2. b 3. d 4. (1) G; (2) W; (3) W; (4) G; (5) W; (6) G; (7) W 5. a

Chapter 14

Check Your Understanding 1. Touch, pain, pressure, vibration, temperature, and proprioception from the somatic organs (skin, body wall, limbs) are general somatic sensations. Taste and smell are special visceral sensations. 2. All spinal nerves carry both sensory and motor fibers, but some cranial nerves are exclusively sensory or primarily motor in function. 3. Nociceptors respond to painful stimuli. These sensory receptors are free nerve endings. 4. Proprioceptors are part of the somatic sensory system (outer tube). 5. Encapsulated receptors are mechanoreceptors (respond to pressure, discriminative touch, vibration, and stretch). 6. The glossopharyngeal nerve (CN IX), the vagus (CN X), and the accessory nerve (CN XI) pass through the jugular foramen. 7. The optic nerve (CN II) carries the special somatic sensation (SSS) for vision, and the vestibulocochlear nerve (CN VIII) carries SSS for hearing and equilibrium. 8. The trigeminal nerve

(CN V) is the “great sensory nerve of the face.” The facial nerve (CN VII) carries motor innervation to the muscles of the face. **9.** A lesion to the dorsal root of spinal nerve T₄ would result in sensory deficits from the muscles and skin of the anterior and posterior trunk in the region of thoracic vertebra T₄ and rib 4. There would be no motor deficits. A lesion to the dorsal ramus of T₄ would result in sensory and motor deficits in the skin and epaxial (dorsal) muscles in the vicinity of thoracic vertebra T₄. **10.** (a) Cervical nerve C₅ exits below cervical vertebra C₄. (b) Lumbar nerve L₃ exits below lumbar vertebra L₃. **11.** The diaphragm is innervated by spinal segments C₃, C₄, and C₅. Innervation from segments C₃ and C₄ would not be affected by an injury at C₅; therefore, independent breathing is possible with an injury in this location. **12.** The radial nerve innervates all of the extensor muscles of the arm and forearm. **13.** Sensory innervation from the medial portion of the hand would be lost, as would the ability to abduct and adduct the hand and extend the fingers (loss of motor innervation to the interossei and medial lumbricals). **14.** The muscles of the upper limb are innervated by nerves off the brachial plexus (C₅–T₁). Injury at C₅ would result in loss of function below the area of injury; thus, the muscles of the upper limb would be paralyzed. **15.** The femoral nerve innervates the muscles of the anterior compartment of the thigh; the obturator nerve innervates the muscles of the medial compartment of the thigh; and the sciatic nerve innervates the muscles of the posterior compartment of the thigh (tibial branch primarily). **16.** The nerves innervating the elbow are the musculocutaneous, radial, median, and ulnar nerves. **17.** Reviewing the dermatome map in Figure 14.16 shows that the skin on the anterolateral surface of the leg is innervated by spinal nerve L₅. Herniation at this level can result in loss of sensation at this dermatome. **18.** Shingles blisters at the level of the navel indicate viral infection in spinal nerve T₉ or T₁₀. **19.** (a) neuralgia = pain in a nerve; (b) paresthesia = beyond sensation, abnormal sensation; (c) neuropathy = disease of the nerves. **20.** Postpolio syndrome is not due to reactivation of the polio virus. It is thought that this syndrome results from the normal degeneration of motor neurons associated with age. Because the motor units of polio survivors are enlarged, loss of motor neurons results in noticeable loss of muscle function.

Review Questions 1. c 2. b 3. (1) d; (2) c; (3) f; (4) b; (5) e; (6) a 4. (1) f; (2) i; (3) b; (4) g,h,j; (5) e; (6) i; (7) i; (8) k; (9) j; (10) c,d,f,k; (11) c 5. (1) b,6; (2) d,8; (3) c,2; (4) c,5; (5) a,4; (6) a, 3&9; (7) a,7; (8) a,7; (9) d,1 6. c 7. c 8. c 9. b 10. a and e

Chapter 15

Check Your Understanding 1. Postganglionic axons are nonmyelinated. 2. The sympathetic division of the ANS has been activated in this near-miss scenario. 3. Sympathetic ganglia are located near the spinal cord and vertebral column (in the sympathetic trunk or collateral ganglia). Most parasympathetic ganglia are located in or near the target organ. 4. Traditionally the ANS is considered a motor division; therefore, it does not include the visceral sensory fibers. 5. Sacral spinal nerves (S₂–S₄) carry preganglionic parasympathetic fibers. 6. (a) Vagal stimulation of the heart decreases heart rate. (b) Vagal stimulation of the small intestine increases motility and secretion. (c) Vagal stimulation of the salivary glands stimulates secretion. 7. The preganglionic fibers synapse in ganglia located along the pathway of the trigeminal nerve (CN V). Postganglionic fibers then travel along CN V to

reach their target organs. 8. The white rami communicantes carry preganglionic outflow from the thoracic and lumbar regions of the cord into the sympathetic trunk. The gray rami communicantes are postganglionic fibers that exit off the sympathetic trunk onto a spinal nerve at each level of the sympathetic trunk. 9. Sympathetic innervation to the abdominal organs decreases activity of the glands and muscles of the digestive system. 10. The thoracic plexuses contain preganglionic parasympathetic fibers and postganglionic sympathetic fibers. The abdominal plexuses also contain preganglionic parasympathetic fibers and postganglionic sympathetic fibers. In addition, preganglionic sympathetic fibers travel through the abdominal plexuses (via the splanchnic nerves) to reach the collateral ganglia. 11. Most visceral pain fibers follow the sympathetic pathway back to the CNS. 12. A peripheral reflex does not involve the CNS at all. Some peripheral reflexes synapse in the sympathetic ganglia, and others occur entirely within the body wall of the target organ (enteric nervous system). 13. The hypothalamus is the main control center of the ANS. 14. Postganglionic neurons are formed from neural crest tissue. 15. The parasympathetic division is deficient in achalasia of the cardia. Raynaud's disease is due to an exaggerated sympathetic vasoconstriction in response to cold.

Review Questions 1. d 2. (1) S; (2) P; (3) P; (4) S; (5) S; (6) P; (7) S; (8) S; (9) P; (10) S; (11) P; (12) S; (13) S; (14) S; (15) S 3. c 4. d 5. b 6. d 7. c 8. a

Chapter 16

Check Your Understanding 1. The receptor cells for taste are epithelial cells. 2. Olfactory receptors are bipolar neurons. These cells are replaced when damaged, making them among the few neurons that undergo replacement throughout adult life. 3. The conjunctiva is a transparent mucous membrane that covers the inner surfaces of the eyelids and the anterior surface of the eye. 4. The lateral rectus is not functioning if the eye is turned in medially. This muscle is innervated by the abducens nerve (CN VI). 5. The cornea is part of the external fibrous layer of the eye, continuous with the sclera. It is a transparent layer covering the anterior one-sixth of the eye. The cornea is composed of dense connective tissue sandwiched between two layers of epithelium. It forms part of the light-bending apparatus of the eye. The choroid is part of the middle vascular layer of the eye. It is a highly vascular, pigmented membrane covering the posterior five-sixths of the eye. Blood vessels of the choroid nourish the eye, and its pigments absorb light. 6. Macular degeneration diminishes the clarity of the visual field straight ahead. 7. The aqueous humor is a clear watery fluid that fills the anterior segment. It supplies nutrients and oxygen to the avascular lens and cornea. It is constantly produced and drained, a process that maintains constant intraocular pressure. 8. The lens becomes rounder when close objects are viewed. 9. The resting eye is set for distance vision. Accommodation for viewing close objects requires elasticity of the lens. As we age, the lens becomes less elastic and cannot accommodate for near vision well. 10. Axons from ganglion cells from the medial half of the retina extend through the right optic nerve and pass through the optic chiasma to the left optic tract. They synapse in the left lateral geniculate nucleus of the thalamus with neurons that extend via the optic radiation to the left primary visual cortex. 11. The retina forms from the outpocketing of the neural tube. 12. The tympanic membrane (eardrum) separates the external acoustic meatus from the middle ear cavity. 13. The four openings

into the middle ear cavity are the pharyngotympanic tube, the round window, the oval window, and the mastoid antrum. 14. The malleus is the auditory ossicle that abuts the tympanic membrane. 15. The membranous labyrinth is a continuous series of membranous sacs and ducts filled with endolymph that contain the sensory receptors for hearing and equilibrium. The bony labyrinth is the cavity within the petrous portion of the temporal bone that surrounds the membranous labyrinth. 16. Perilymph is located in the scala vestibuli and the scala tympani of the cochlea. 17. The vestibular membrane forms the roof of the cochlear duct; the basilar membrane forms the floor; and the tectorial membrane sits atop the sensory hair cells. Vibrations in the tectorial membrane stimulate the hair cells of the spiral organ. 18. The maculae of the utricle and the saccule monitor stationary head position and linear acceleration. 19. Sensorineural deafness results from damage to the cells of the spiral ganglion. 20. The membranous labyrinth is formed from ectoderm. 21. The vestibular nuclei of the medulla and the cerebellum are the major processing centers for input from the vestibular nerves.

Review Questions 1. a 2. d 3. c 4. b 5. b 6. b 7. e 8. b 9. c 10. b 11. d 12. b

Chapter 17

Check Your Understanding 1. Hormones circulate throughout the body in the bloodstream. They leave the bloodstream at the capillaries and enter the tissue fluid. Although hormones encounter all types of cells, they influence the activity only of their target cells. 2. Endocrine secretions are regulated via humoral stimuli (concentrations of specific substances in the blood); nervous stimuli (direct nerve innervation); or hormonal stimuli (releasing and inhibiting hormones secreted by other endocrine tissues). 3. Tropic hormones secreted by the pituitary regulate the secretion of hormones by other endocrine glands. The nontropic pituitary hormones act directly on nonendocrine target tissues. 4. The hormones secreted by the posterior pituitary are produced in the neuron cell bodies located in the hypothalamus. The anterior pituitary hormones are produced by the cells of this gland. 5. (a) The target organs for oxytocin are the uterus and the breast. (b) ACTH acts on the adrenal cortex. (c) FSH acts on the ovaries in females and the testes in males. (d) The target organ for ADH is the kidneys. 6. A patient with hypothyroidism would not have concerns about blood calcium regulation because this disorder refers to low levels of thyroid hormone, not calcitonin levels. 7. Aldosterone is produced in the outer layer, the zona glomerulosa, of the adrenal cortex. 8. The adrenal medulla secretes the hormones norepinephrine (a sympathetic neurotransmitter) and epinephrine when stimulated by preganglionic sympathetic neurons. The cells of the adrenal medulla have no axonal processes, but rather release their secretions into the blood of nearby capillaries. 9. Glucocorticoid secretion is stimulated by ACTH, which is produced by the anterior pituitary. 10. The endocrine cells of the pancreas are distributed throughout the pancreas in clusters of cells called the pancreatic islets. 11. In a developing fetus, estrogens and progesterone are produced by the placenta. 12. Addison's disease results from hyposecretion of the adrenal cortex. Typical symptoms are low blood pressure, dehydration, fatigue, and loss of appetite. Graves' disease is caused by hypersecretion of the thyroid. Symptoms are elevated metabolic rate, rapid heart rate, sweating, and weight loss. Cushing's disease results from hypersecretion of glucocorticoid hormones from the adrenal cortex. High blood

glucose levels, lethargy, swollen face, and development of a “buffalo hump” are symptoms.

Review Questions 1. d 2. (a) 2; (b) 5; (c) 1; (d) 4; (e) 3 3. a 4. c 5. a 6. (1) c; (2) b; (3) a; (4) c; (5) a; (6) b; (7) f; (8) b; (9) a; (10) a; (11) a; (12) e 7. d

Chapter 18

Check Your Understanding 1. The percentage of blood volume composed of erythrocytes is called the hematocrit. Its normal value is around 45%. 2. The three main plasma proteins are albumin (prevents water from leaving the bloodstream), globulins (antibodies and proteins that transport lipids, iron, and copper) and fibrinogen (involved with blood clotting). 3. Erythrocytes and platelets do not contain nuclei. 4. *Leukocyte* refers to all types of white blood cells; lymphocytes are specific white blood cells that are part of the immune system. 5. Wright's stain is composed of the acidic stain eosin, which binds to basic cellular elements and stains them pink, and the basic stain methylene blue, which binds to acidic cellular elements, staining them blue to purple in color. The cytoplasm of neutrophils takes up both stains, thus their name, “neutral.” Eosinophils are “eosin loving,” and the cytoplasmic granules stain pink. The granules in basophils (“basic loving”) take up the basic stain methylene blue, and the cytoplasm of these cells is blue to purple in color. 6. In adults, blood stem cells are located in the spongy bone of the axial skeleton and limb girdles and in the proximal epiphysis of the humerus and femur. 7. The fibrous network within red bone marrow is formed from reticular connective tissue. 8. Lymphocytes form from lymphoid stem cells. All other blood cells form from myeloid stem cells. 9. Symptoms of anemia are fatigue, shortness of breath, and low body temperature. Low levels of erythrocytes or hemoglobin concentration result in poor oxygenation of body tissues. 10. The spleen and the liver are the major fetal hematopoietic organs before month 7. 11. The T cells in cord blood are immature and therefore less likely to cause tissue rejection.

Review Questions 1. b 2. d 3. b 4. c 5. e 6. a 7. d 8. d 9. c 10. b 11. d

Chapter 19

Check Your Understanding 1. The right side of the heart receives and pumps deoxygenated blood. 2. The apex of the heart is located on the left mid-clavicular line at intercostal space 5 (ICS 5). 3. The epicardium is the visceral layer of the serous pericardium. 4. (a) Pectinate muscles are located in both atria. (b) Papillary muscles are found in both ventricles. (c) The fossa ovalis is in the right atrium. (d) The trabeculae carneae are muscular ridges located in both ventricles. 5. The superior vena cava, inferior vena cava, and coronary sinus are the three major veins that empty into the right atrium. (The anterior cardiac veins, small veins that drain the right ventricle, also empty into the right atrium.) 6. From the aortic semilunar valve, blood enters into the aorta, the great artery that carries oxygenated blood to the systemic circuit. 7. During ventricular systole, the AV valves are closed, and the semilunar valves are open. 8. A stenotic valve has a narrowed opening due to fusion or stiffening of the cusps and thus doesn't open properly. An incompetent valve is a leaky valve that doesn't close completely. Both valve disorders reduce the efficiency of the heart. 9. Gap junctions allow the stimulus to contract to be passed from one muscle cell to an adjacent cell. This linkage between muscle cells enables all the muscle cells in a heart chamber to contract at the same time. 10. The “pacemaker” of the heart is the

sinoatrial (SA) node. It is located in the right atrium and is composed of specialized cardiac muscle cells that initiate the electrical signal that sets heart rate. 11. Sympathetic innervation to the heart increases heart rate and increases strength of contraction. Parasympathetic innervation only influences heart rate; it decreases heart rate. 12. The left coronary artery supplies blood to the left ventricle via two branches: The anterior wall receives blood from the left interventricular artery, and the posterior wall is supplied by the circumflex artery. 13. Risk factors for coronary artery disease include high blood pressure, smoking, high cholesterol levels, diabetes, inactivity, and family history of heart disease. For lucky individuals, the first symptom is angina; for unlucky individuals, a fatal heart attack is the first symptom. 14. An opening in the interventricular septum would allow oxygenated and deoxygenated blood to mix. Because the left ventricle is stronger, more blood is shunted from the left ventricle to the right ventricle. 15. The embryonic ventricle forms the left ventricle. 16. Regular and vigorous exercise is the most important factor for maintaining a healthy heart throughout life.

Review Questions 1. d 2. b 3. b 4. (1) intima; (2) externa; (3) externa; (4) externa; (5) media; (6) intima 5. a 6. b 7. c 8. b 9. c 10. d 11. a 12. d 13. a 14. b 15. c 16. a

Chapter 20

Check Your Understanding 1. Capillary walls are composed of a single layer of endothelial cells through which diffusion can occur readily. Capillary diameter is similar to that of a red blood cell (RBC), which maximizes the surface contact between the RBC and the capillary walls and thus maximizes gas diffusion. In addition, capillaries are permeable, so fluid and dissolved molecules move readily from the blood plasma to the tissue fluid. 2. The thick smooth muscle of the tunica media and the internal and external elastic membranes that surround this layer function to keep blood pulsing through arteries. Venous blood flow is maintained by valves that prevent backflow, by normal body movement, and by the skeletal muscle pump. 3. (a) Vasa vasorum are small vessels in the tunica externa of larger arteries that supply the outer layers of these large vessels. (b) Arterial anastomoses are junctions between two different arteries that supply a common organ. (c) Varicose veins form when the valves of a vein fail and blood pools in the vessel. (d) An artery is a vessel that carries blood away from the heart. 4. The pulmonary artery is illustrated in blue because it is carrying deoxygenated blood (toward the lung to be oxygenated). This vessel is carrying blood away from the heart; thus, it is an artery. 5. The brachiocephalic trunk supplies the head, neck, thorax, and upper limb on the right side. The left common carotid artery supplies the left portions of the head and neck, and the left subclavian artery supplies the thorax and upper limb on the left side. 6. The four major vessels that supply blood to the brain are the right and left internal carotid arteries and the right and left vertebral arteries. The internal carotids branch off the common carotid arteries; the vertebral arteries branch off the subclavian arteries. 7. (a) The femoral artery in the thigh; (b) the brachial artery in the arm; (c) the radial artery at the wrist; (d) the dorsalis pedis artery in the foot; (e) the common carotid artery in the neck. 8. The celiac trunk supplies the stomach, liver, gallbladder, pancreas, spleen, and part of the small intestine. The superior mesenteric artery supplies the small intestine, the ascending colon, and part of the transverse colon. The inferior mesenteric artery supplies the distal portion of the transverse colon, the descending colon, and rectum. 9. The hepatic portal

vein drains the organs of the digestive tract, enters the liver, and empties into the liver sinusoids. The hepatic veins drain blood from the liver and empty into the inferior vena cava. 10. (a) The cephalic vein is a superficial vein of the upper limb. (b) The popliteal vein is located on the posterior knee in the popliteal fossa. (c) The transverse sinus is in the head. It is one of the dural sinuses that drains the brain. (d) The saphenous vein is a superficial vein of the lower limb. (e) The azygos vein runs along the right posterior thoracic wall. 11. The median cubital vein is a common site for withdrawing blood. The saphenous vein is commonly used in coronary artery bypass surgery. 12. Factors that contribute to atherosclerosis are smoking, a high-fat diet, and a sedentary lifestyle. 13. The basement membrane of capillaries thickens in diabetes mellitus. This reduces the rate of the diffusion of gases and nutrients to the body tissues. 14. The umbilical vein carries the most highly oxygenated blood in the fetus. 15. The ductus arteriosus extends between the pulmonary trunk and the aorta. Blood in the pulmonary trunk is shunted to the aorta, and thus the pulmonary circuit is bypassed.

Review Questions 1. c 2. c 3. a 4. b 5. e 6. b 7. a,c 8. c 9. a 10. d 11. d

Chapter 21

Check Your Understanding 1. The endothelial cells of lymphatic capillaries have few intercellular junctions, and the edges of adjacent cells overlap, forming easily opened minivalves. Blood capillaries contain intercellular clefts between adjacent cells and, in some cases, pores that cause these vessels to be permeable. 2. The sentinel node in a throat cancer patient would be a cervical node; in a breast cancer patient, it would be an axillary node; in a cervical cancer patient, it would be an inguinal node. 3. Intestinal trunk; thoracic duct; left internal jugular and left subclavian veins. 4. Cytotoxic T lymphocytes gain immunocompetence in the thymus. 5. Infection caused by a bacterial agent will activate B lymphocytes. 6. B lymphocytes are in the lymphoid follicles. Each lymphoid follicle is derived from the activation of a single B cell. Cell division occurs at the germinal center, producing new B cells that then migrate from the follicle to become plasma cells. 7. In the red pulp of the spleen, defective blood cells are phagocytized by macrophages. 8. In the lymph nodes, T lymphocytes are located in the deeper portions of the cortex and in the medullary cords of the medulla. 9. Aggregated lymphoid nodules are located in the ileum of the small intestine. 10. The red lines indicate lymphangitis, inflammation of a lymphatic vessel due to infection. 11. The thymus is derived from endoderm. The tonsils, spleen, and lymph nodes are all from mesoderm.

Review Questions 1. d 2. b 3. d 4. a 5. (1) b; (2) b; (3) a; (4) b; (5) c 6. (1) c; (2) d; (3) e; (4) a; (5) b 7. a 8. c 9. c 10. d

Chapter 22

Check Your Understanding 1. The nasal cavity, including the nasal conchae, paranasal sinuses, and the nasopharynx, is covered with respiratory mucosa. This mucous membrane functions to warm, filter, and moisten inhaled air. 2. External respiration is gas exchange between the blood and the air in the air sacs of the lungs. Internal respiration is gas exchange between the blood and the body tissues. Cellular respiration is the use of oxygen by cells to convert glucose into cellular energy (ATP). 3. The pharynx, commonly called the throat, is located posterior to the nasal and oral cavities and extends inferiorly to the larynx and esophagus. The larynx, or voice box, is at the top of the trachea. It houses the vocal

cords and functions as a gateway to prevent food from entering the airway. **4.** The inferior boundary of the nasopharynx is the uvula, that of the oropharynx is the epiglottis, and that of the laryngopharynx are the openings of the larynx and esophagus. **5.** The vocal folds attach to the arytenoid cartilages posteriorly and extend anteriorly to the thyroid cartilage. **6.** The mucous membrane lining the trachea and large bronchi secretes mucus, which traps dust and foreign particles. The ciliated epithelium sweeps this dust-laden mucus up toward the pharynx, where it is swallowed. In the alveoli, alveolar macrophages remove foreign particles by phagocytosis. **7.** At the level of the bronchioles (tubules with a diameter of 1 mm or less) cartilage plates are no longer present in the tube wall. Elastin is found in the tubule walls throughout the bronchial tree, all the way down to the alveoli. **8.** The respiratory membrane is composed of the endothelial cells of the pulmonary capillaries, the simple squamous epithelium (type I cells) of the alveolar wall, and the fused basal lamina of these tissues. **9.** The horizontal fissure separates the superior and middle lobes of the right lung. **10.** From superior to inferior, the pulmonary artery, the main bronchus, and the pulmonary vein enter the left lung at the hilum. **11.** A stab wound at rib 7 in the midclavicular line would not puncture a lung, but it would puncture the pleural cavity (see Figure 22.13). **12.** Contraction of the diaphragm increases the volume of the thoracic cavity. This volume change decreases the pressure in the pleural cavity, causing air to enter the lungs. **13.** If the pleural cavity is punctured in a stab wound, atmospheric air enters the pleural cavity—thus the “sucking” sound produced by this injury. The loss of the pressure differential between the lung and the pleural cavity results in collapse of the lung. **14.** The accessory inspiratory muscles include the scalenes, sternocleidomastoid, and pectoralis minor, which all aid in elevating the ribs. Primarily it is the abdominal muscles (the obliques and transversus abdominis) that are active during forced expiration. **15.** The respiratory centers of the brain stem (ventral respiratory group or VRG, with input from neurons in the pons and dorsal respiratory group) set the basic respiratory rhythm. The VRG neurons stimulate the somatic motor neurons that innervate the respiratory muscles. **16.** Emphysema destroys the alveolar walls in the respiratory zone. **17.** “Smoker’s cough” is a symptom of chronic bronchitis, a COPD disease. Excess secretion of mucus, bronchial inflammation, and fibrosis in response to chronic exposure to smoke cause persistent and productive coughing. **18.** The lungs are not fully formed until late in fetal development. Specifically, the alveoli form at 24 weeks, and type II alveolar cells begin to produce surfactant at 26 weeks.

Review Questions 1. c 2. a 3. (1) d; (2) d; (3) d; (4) c; (5) c; (6) c 4. (1) d; (2) c; (3) f; (4) a; (5) b; (6) e 5. a 6. a 7. a,d 8. d 9. b 10. a 11. a 12. (1) e; (2) a; (3) b; (4) d; (5) c 13. b 14. d 15. d 16. (1) e; (2) h; (3) c; (4) b; (5) g; (6) a; (7) f; (8) d 17. a 18. (1) a; (2) b; (3) c; (4) a; (5) b; (6) c; (7) b

Chapter 23

Check Your Understanding 1. Propulsion occurs throughout the alimentary canal, from the oral cavity to the anus. 2. The abdominal cavity is the region ventral body cavity extending from the diaphragm to the pelvis. The peritoneal cavity is the space between the parietal and visceral serous membranes: the parietal peritoneum and visceral peritoneum. The pancreas, duodenum, ascending colon, descending colon, and rectum are secondarily retroperitoneal. 3. (a) The mesenteries to the liver are the falciform ligament and the lesser omentum, both ventral

mesenteries. (b) The mesenteries attached to the stomach are the greater omentum, a dorsal mesentery, and the lesser omentum. (c) The mesentery to the sigmoid colon is the sigmoid mesocolon, a dorsal mesentery. 4. Blood from a hemorrhaging spleen or liver would collect in the peritoneal cavity. 5. From the lumen outward, the sublayers of the mucosa are the epithelium, lamina propria and muscularis mucosae. The intrinsic glands are formed from the epithelial layer. 6. Peristalsis and segmentation result from contractions of the smooth muscle of the muscularis externa. 7. The cells of smooth muscle are elongated with tapering ends, contain a single centrally located nucleus, and are nonstriated. Smooth muscle is innervated by the ANS and contracts in response to hormones, stretching, and nerve stimulation. It is extremely fatigue resistant. Skeletal muscle is composed of multinucleated, striated, cylindrically shaped cells. Skeletal muscle is innervated by somatic motor neurons and is less fatigue resistant than smooth muscle. 8. Stratified squamous epithelium composes the mucosa of the oral cavity, oropharynx, and laryngopharynx. 9. The three salivary glands are the parotid, the submandibular, and the sublingual. Their secretions initiate the digestion of carbohydrates. 10. The trigeminal nerve (CN V) innervates the teeth: the maxillary branch (CN V₂) to the teeth in the upper jaw; the mandibular branch (CN V₃) to the teeth in the lower jaw. 11. The mucosal epithelium changes from stratified squamous in the esophagus to simple columnar in the stomach. The muscularis externa in the stomach has an additional deep layer, the oblique layer. 12. The stomach is located in the left hypochondriac, epigastric, and umbilical regions of the abdomen. 13. Chief cells produce pepsinogen; parietal cells produce HCl; the surface epithelia secrete bicarbonate-buffered mucus. 14. Intestinal epithelial cells live for 3–6 days. These cells are replaced by cells from the rapidly dividing undifferentiated epithelial cells that line the intestinal glands. 15. The portions of the large intestine are the cecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum, and anal canal. 16. The end products of carbohydrate and protein digestion are absorbed into the capillary network within the villus; absorbed fats are absorbed into the lacteal. 17. The right and left hepatic arteries carry oxygen-rich blood into the liver; the right and left hepatic portal veins carry nutrient rich blood into the liver; and the right and left hepatic ducts carry bile out of the liver. 18. The path of blood from the digestive tract through the liver lobule is as follows: from the hepatic portal vein, to the portal venules in the portal triad at the periphery of a liver lobule, through the liver sinusoids, into the central vein of the lobule. 19. The acinar cells of the pancreas produce and secrete digestive enzymes. These secretions empty into the duodenum. 20. Many diseases are passed through fecal contamination of food and water. Washing your hands after using the restroom is an effective means to prevent the spread of infection. 21. The mucosal epithelium is derived from endoderm. The submucosa and muscularis externa are derived from splanchnic lateral plate mesoderm. 22. The superior mesenteric artery supplies the structures that develop from the embryonic midgut.

Review Questions 1. d 2. b 3. c 4. c 5. d 6. b 7. e 8. e 9. a 10. c 11. b 12. b 13. (a) 1; (b) 6; (c) 12; (d) 3; (e) 7; (f) 10; (g) 2; (h) 5; (i) 9; (j) 11; (k) 4; (l) 8 14. (1) c; (2) d; (3) e; (4) b; (5) a

Chapter 24

Check Your Understanding 1. The kidneys are superficial to the parietal peritoneum, so they are not within the peritoneal cavity; they are retroperitoneal. They are, however, in the abdominal cavity. 2. The

kidneys extend from the eleventh or twelfth thoracic vertebra superiorly to the third lumbar vertebra inferiorly. The right kidney is slightly inferior to the left because the liver takes up much of the upper right abdominal quadrant. 3. The interlobar arteries and veins pass through the renal columns. 4. The glomerular capillaries, glomerular capsule, and the proximal and distal convoluted tubules are located exclusively in the renal cortex. The nephron loop and the collecting duct extend into the medulla. 5. Filtration occurs at the glomerular capillaries. Secretion and reabsorption occur across the peritubular capillaries. 6. The juxtaglomerular apparatus functions in blood pressure regulation. The cells at the terminal portion of the nephron loop are elongated where they abut the afferent arteriole. These cells monitor filtrate solute concentration and initiate a response when this concentration falls below a certain level. 7. The ureter carries urine from the kidney to the urinary bladder. The urethra carries urine from the urinary bladder to the outside of the body. 8. Transitional epithelium lines the ureter, bladder, and proximal urethra. 9. The external urethral sphincter is innervated by somatic (voluntary) motor neurons. 10. The urethra in females is much shorter than in males and is located close to the vaginal and anal openings. Bacteria from these regions can readily enter the urethra, particularly during sexual activity. 11. All three pairs of kidneys—pronephros, mesonephros, and metanephros—form from intermediate mesoderm. 12. A cloaca is the common opening of the digestive tract and the urinary and reproductive ducts.

Review Questions 1. d 2. (1) d; (2) c; (3) d; (4) c; (5) e 3. d 4. a 5. d 6. e 7. a 8. a 9. a 10. b 11. c 12. d 13. d 14. c 15. (a) 1; (b) 4; (c) 2; (d) 6; (e) 7; (f) 3; (g) 9; (h) 5; (i) 8; (j) 10 16. b 17. a 18. (1) a; (2) c; (3) b; (4) d; (5) c; (6) e

Chapter 25

Check Your Understanding 1. Interstitial cells are clustered in the loose connective tissue between the seminiferous tubules (thus their name). These cells secrete testosterone. 2. The tunica albuginea is the fibrous capsule covering the testis. The tunica vaginalis is superficial to the tunica albuginea. It is a two-layered serous sac (a remnant of the peritoneum) that partially surrounds the testis. 3. In the epididymis, sperm gain the ability to swim and the ability to fertilize the egg. 4. The ejaculatory duct is located at the junction of the ampulla of the ductus deferens and the duct of the seminal vesicle. This duct passes through the prostate and empties into the prostatic urethra. 5. Approximately 60% of the volume of semen is produced by the seminal vesicles. 6. The urethra passes through the corpus spongiosum and thus is called the spongy urethra. 7. Each primary spermatocyte produces four spermatids. 8. Sustentocytes help form sperm by nourishing spermatogenic cells and moving these cells toward the tubule lumen. Secretions from sustentocytes influence testosterone and FSH levels and function either to stimulate or to inhibit sperm formation. Tight junctions between adjacent sustentocytes form the blood-testis barrier, which protects sperm from attack by the immune system. 9. The head of the sperm contains the nucleus and the acrosome; the midpiece contains mitochondria; and the tail is a flagellum. 10. The uterine tubes are lined with ciliated and unciliated columnar epithelium. The beating of the cilia produces movement of the peritoneal fluid to draw the oocyte into the uterine tube. 11. Peritoneal folds that support the female reproductive structures are the broad ligament composed of the mesometrium to the uterus, the mesosalpinx to the uterine tubes, and the mesovarium and suspensory ligament to the ovary. 12. (a) The

fundus of the uterus is the region superior to the entrance of the uterine tubes. (b) The infundibulum is the lateral funnel-shaped opening of the uterine tube. (c) The endometrium is the innermost layer of the uterine wall. **13.** Follicle-stimulating hormone (from the anterior pituitary) stimulates follicle development in the ovary. **14.** Oogonia differentiate into oocytes during the fetal period in females. In males, spermatogonia differentiate into spermatocytes throughout a male's adult life. **15.** The corpus luteum is the remnant of the ovarian follicle after ovulation. The corpus luteum secretes progesterone, which stimulates the secretory phase of the uterine cycle. **16.** (a) The female labia majora are homologous to the male scrotum. (b) The clitoris is homologous to the penis. (c) The bulb of the vestibule is homologous to the corpus spongiosum. **17.** The

glandular portion of the breast develops midway through pregnancy. **18.** Once a sperm fuses to the plasma membrane of the oocyte, the cortical reaction prevents additional sperm from binding to and entering the egg. **19.** The decidua basalis is from the maternal endometrium; the chorionic villi are from the embryonic trophoblast. **20.** The placenta produces progesterone and human chorionic gonadotropin (HCG) throughout the pregnancy and produces estrogens and corticotropin-releasing hormone toward the end of gestation. **21.** (a) PSA tests are used to screen for prostate cancer. (b) Pap smears screen for cervical cancer. (c) Mammography screens for breast cancer. (d) Self-examination of the testicles is advised as screening for testicular cancer. **22.** In a male embryo, the mesonephric duct forms the efferent ductules, the epididymis, the

ductus deferens, and the ejaculatory duct. The paramesonephric ducts degenerate in a male embryo.

23. The testosterone-induced secondary sex characteristics in males are pubic, facial, and axillary hair; enlargement of the larynx; increased secretion of sebaceous glands; and increased skeletal and muscular mass. In females, estrogen-induced secondary sex characteristics include an increase in subcutaneous fat at the hips and breast and widening of the pelvic girdle.

Review Questions **1.** a **2.** (1) c; (2) b; (3) g; (4) h; (5) d; (6) e; (7) f; (8) i; (9) a; (10) j; (11) b,h; (12) i **3.** a **4.** (1) a; (2) b; (3) a; (4) b; (5) b; (6) a **5.** (1) e; (2) a; (3) a&c; (4) d; (5) b **6.** d **7.** a **8.** d **9.** c **10.** (1) b,j; (2) a,g; (3) c,f; (4) d,h; (5) e,i **11.** a,c,d,e,g,h,j

Glossary

PRONUNCIATION KEY

The pronunciation key that is used throughout this book takes advantage of the fact that in scientific terms, long vowels usually occur at the end of syllables, whereas short vowels usually occur at the beginning or in the middle of syllables. Therefore:

1. When vowels are *unmarked*, they have a long sound when they occur at the end of a syllable, and a short sound when they are at the beginning or in the middle of a syllable. For example, in the word *kidney* (kid'ne), you automatically know that the middle 'i' is short and the terminal 'e' sound is long. In the word *renal* (re'nal), the 'e' is long, and the 'a' is short.
2. When a vowel sound violates the above rule, it is marked with a short or long symbol. Only those short vowels that come at the end of a syllable are marked with the short symbol, called a breve (˘); and only those long vowels that occur at the start or middle of a syllable are marked with a long symbol (–). For example, in the word *pelvirectal* (pel˘vĩ-rek'tal), all four vowels are short, but only the 'i' is marked as short, because it is the only vowel that falls at the end of a syllable. In *methane* (meth'ān), the long 'a' is marked as such because it does not fall at the end of a syllable.
3. Short 'a' is *never* marked with a breve. Instead, short 'a' at the end of a syllable is indicated by 'ah.' For example, in the word *papilla* (pah-pil'ah), each 'a' is short and pronounced as 'ah.'
4. In words that have more than one syllable, the syllable with the strongest accent is followed by a prime (') mark, and syllables with the second strongest accent, where present, are indicated with a double prime ("). The unaccented syllables are followed by dashes. An example of these principles is the word *anesthetic* (an˘es-thet'ik), in which *thet'* is emphasized most strongly, *an˘* has a secondary emphasis, and the other two syllables are not spoken with any emphasis.

Abdomen (ab-do'men) Region of the body between the diaphragm and the pelvis.

Abduct (ab-duct') To move away from the midline of the body.

Absorption Process by which the products of digestion pass through the lining of the alimentary canal into the blood or lymph.

Accessory digestive organs Organs that contribute to the digestive process but are not part of the alimentary canal, including the tongue, teeth, salivary glands, pancreas, liver, and gallbladder.

Acetabulum (as˘ĕ-tab'u-lum) Cuplike cavity on lateral surface of hip bone that receives the femur.

Actin (ak'tin) A contractile protein in cells, especially abundant in muscle cells.

Action potential A large, transient depolarization event, including polarity reversal, that is conducted along the plasma membrane of a nerve axon or muscle cell without diminishing in intensity; also called a *nerve impulse*.

Acute Producing severe symptoms in the short term; rapidly developing.

Adduct (ah-duct') To move toward the midline of the body.

Adenohypophysis (ad˘ĕ-no-hi-pof'ĩ-sis) One of the main divisions of the pituitary gland, the other being the neurohypophysis; the glandular part of the pituitary.

Adenoids (ad˘ĕ-noids) The pharyngeal tonsil on the roof of the pharynx.

Adenosine triphosphate (ATP) (ah-den'o-sĕn) Molecule in cells that stores and releases chemical energy for use in body cells.

Adipose (ad'ĩ-pōs) Fatty.

Adrenal gland (ah-dre'nal) Hormone-secreting gland located superior to the kidney; consists of medulla and cortex areas; also called *suprarenal gland*.

Adrenaline (ah-dren'ah-lin) *See* Epinephrine.

Adrenocorticotrophic hormone (ACTH) (ah-dre˘no-kor˘tĩ-ko-trop'ik) Hormone from the anterior pituitary that influences the activity of the adrenal cortex.

Adventitia (ad˘ ven-tish'e-ah) Outermost layer or covering of an organ; consists of connective tissue.

Aerobic (a'er-ōb-ik) Requiring oxygen.

Afferent (af'er-ent) Carrying to or toward; especially a nerve fiber that carries impulses toward the central nervous system; afferent neurons are sensory neurons.

Agonist (ag'o-nist) Muscle that bears primary responsibility for causing a certain movement; also called a *prime mover*.

AIDS (acquired immune deficiency syndrome) Disease caused by the human immunodeficiency virus (HIV): symptoms include severe weight loss, swollen lymph nodes, and many opportunistic infections that lead to death.

Aldosterone (al-dos'ter-ōn) Hormone secreted by the adrenal cortex that stimulates resorption of sodium ions and water from the kidney.

Alimentary canal (al'ĩ-men'tar-e) The digestive tube, extending from the mouth to the anus; its basic regions are the oral cavity, pharynx, esophagus, stomach, and small and large intestines.

Allantois (ah-lan'to-is) A tubular extension of the embryonic hindgut and cloaca; becomes the urachus, a fibrous cord attached to the adult bladder.

Alveolus (al-ve'o-lus) (1) One of the microscopic air sacs of the lungs; (2) a spherical sac formed by the secretory cells in a gland; also called an *acinus*; (3) the socket of a tooth.

Amino acid (ah-me'no) Organic compound containing nitrogen, carbon, hydrogen, and oxygen; building block of proteins.

Amnion (am'ne-on) Membrane that forms a fluid-filled sac around the embryo and fetus.

Amphiarthrosis (am˘fe-ar-thro'sis) A slightly movable joint.

Anaerobic (an˘a-er-o'bik) Not requiring oxygen.

Anastomosis (ah-nas"to-mo'sis) A union or joining of blood vessels or other tubular structures.

Androgen (an'dro-jen) A male sex hormone, the main example of which is testosterone.

Anemia (ah-ne'me-ah) Reduced oxygen-carrying capacity of the blood; results from too few erythrocytes or from abnormal hemoglobin.

Aneurysm (an'u-rizm) Blood-filled dilation of a blood vessel, caused by a weakening of the vessel wall.

Angina pectoris (an-ji'nah) Severe, suffocating chest pain caused by temporary lack of oxygen supply to heart muscle.

Antagonist (an-tag'o-nist) Muscle that reverses, or opposes, the action of another muscle.

Anterior The front of an organism, organ, or body part; the ventral direction.

Anterior lobe of pituitary See Adenohypophysis.

Antibody A protein molecule that is secreted by a plasma cell (a cell derived from an activated B lymphocyte) and that binds to an antigen in immune responses.

Antidiuretic hormone (ADH) (an'ti-di"u-ret'ik) Hormone produced by the hypothalamus and released by the posterior part of the pituitary gland (pars nervosa); stimulates the kidney to resorb more water.

Antigen (an'ti-jen) A molecule that is recognized as foreign by the immune system, activates the immune system, and reacts with immune cells or antibodies.

Anus (a'nus) The opening at the distal end of the alimentary canal.

Aorta (a-or'tah) Major systemic artery; arises from the left ventricle of the heart.

Apocrine gland (ap'o-krin) A type of sweat gland in the armpit and anal-genital regions; produces a secretion containing water, salts, proteins, and lipids.

Aponeurosis (ap'o-nu-ro'sis) Fibrous sheet connecting a muscle to the body part it moves.

Appendicular skeleton (ap'en-dik'u-lar) Bones of the limbs and limb girdles that are attached to the axial skeleton.

Apoptosis (ap'o-to'sis) Programmed cell death. Controlled cellular suicide that eliminates cells that are stressed, unneeded, excessive, or aged.

Aqueous humor (a'kwe-us) Watery fluid in the anterior segment of the eye.

Arachnoid mater (ah-rak'noid ma'ter) The weblike middle layer of the three meninges.

Areola (ah-re'o-lah) Circular, pigmented area of skin surrounding the nipple.

Arrector pili (ah-rek'tor) Tiny band of smooth muscle attached to each hair follicle; its contraction causes the hair to stand upright.

Arteriole (ar-te're-öl) A minute artery.

Arteriosclerosis (ar-te're-o-sklë-ro'sis) Hardening of the arteries: any of a number of degenerative changes in the walls of arteries leading to a decrease in their elasticity. (See Atherosclerosis.)

Artery Vessel that carries blood away from the heart.

Arthritis (ar-thri'tis) Inflammation of joints.

Articular capsule (ar-tik'u-lar) The capsule of a synovial joint; consists of an outer layer of fibrous connective tissue and an inner synovial membrane.

Articulation Joint; point where two elements of the skeleton meet.

Atherosclerosis (ath'er-o"skle-ro'sis) Changes in the walls of large arteries involving the deposit of lipid plaques; the most common variety of arteriosclerosis.

Atlas First cervical vertebra.

Atria (a'tre-ah) Paired, superiorly located heart chambers that receive blood returning to the heart (singular: atrium).

Atrioventricular bundle (AV bundle) (a'tre-o-ven-trik'u-lar) Bundle of cardiac muscle cells that conducts impulses from the AV node to

the walls of the right and left ventricles; located in the septum (wall) between the two ventricles of the heart; also called *bundle of His*.

Atrioventricular node (AV node) Specialized mass of conducting cells located in the interatrial septum of the heart.

Atrophy (at'ro-fe) Reduction in size or wasting away of an organ or tissue.

Auditory ossicles (os'ŷ-k'lz) The three tiny bones in the middle ear: malleus (hammer), incus (anvil), and stapes (stirrup).

Autonomic nervous system (ANS) (aw"to-nom'ik) General visceral motor division of the peripheral nervous system; innervates smooth and cardiac muscle, and glands.

Avascular (a-vas'ku-lar) Having no blood supply; containing no blood vessels.

Axial skeleton Portion of the skeleton that forms the central (longitudinal) axis of the body; includes the bones of the skull, the vertebral column, and the bony thorax.

Axilla (ak-sil'ah) Armpit.

Axis (1) Second cervical vertebra; (2) imaginary line about which a joint or structure rotates.

Axon Neuron process that carries impulses away from the cell body.

B cells Lymphocytes that oversee humoral immunity; they divide to generate plasma cells, which secrete antibodies; also called *B lymphocytes*.

Basal ganglia Areas of gray matter located deep within the white matter of the cerebral hemispheres; regulate certain aspects of movement.

Basal lamina A thin sheet of protein that underlies an epithelium.

Basement membrane A layer between an epithelium and the underlying connective tissue; consists of both a basal lamina and a network of reticular fibers.

Basophil (ba'so-fil) (1) Type of white blood cell whose cytoplasmic granules stain purple with the basic dyes in blood stains; mediates late stages of inflammation. (2) A gland cell in the anterior pituitary containing cytoplasmic granules that stain with basic dyes.

Benign (be-nĭn) Not malignant; not life-threatening.

Biceps (bi'seps) Two-headed, especially applied to certain muscles.

Bile Greenish fluid secreted by the liver, stored in the gallbladder, and released into the small intestine; helps start the breakdown of fats.

Biopsy (bi'op-se) Removing a piece of living tissue to examine it under a microscope. Usually done to diagnose a suspected disease condition.

Bipolar neuron Neuron with just two processes, which extend from opposite sides of the cell body.

Blastocyst (blas'to-sist) Stage of early embryonic development; a hollow ball of cells; the product of cleavage.

Blood-brain barrier The feature that inhibits passage of harmful materials from the blood into brain tissues; reflects relative impermeability of brain capillaries.

Blood pressure Force exerted by blood against a unit area of the blood vessel walls; differences in blood pressure between different areas of the circulation provide the driving force for blood circulation.

Blood stem cell The cell type, present throughout life, from which all blood cells (erythrocytes, leukocytes, platelets) arise. Present in the bone marrow. It gives rise not only to blood cells, but also to mast cells, osteoclasts, and dendritic cells of the immune system. Also called *pluripotential hematopoietic stem cell*.

Bolus (bo'lus) A rounded mass of food prepared by the mouth for swallowing.

Bone remodeling Process involving bone formation and bone destruction in response to mechanical and hormonal factors.

Brain stem Collectively, the midbrain, pons, and medulla of the brain.

Bronchus Any of the air tubes of the respiratory tree between the trachea and bronchioles; bronchi enter and branch within the lungs.

Bursa A fibrous sac lined with synovial membrane and containing synovial fluid; occurs between bones and tendons (or other structures), where it acts to decrease friction during movement.

- Calcaneal (Achilles) tendon** Tendon that attaches the calf muscles to the heel bone.
- Calcitonin** (kal"si-to'nin) Hormone released by the thyroid gland that promotes a decrease in calcium levels in the blood.
- Calyx** (ka'liks) A cuplike tributary of the pelvis of the kidney.
- Cancer** A malignant, invasive cellular tumor that has the capability of spreading throughout the body or body parts.
- Capillary** The smallest of blood vessels and the site of exchanges of molecules between the blood and the tissue fluid.
- Carcinogen** (kar-sin'o-jen) Cancer-causing agent.
- Cardiac muscle** Muscle tissue of the heart wall.
- Cardiac sphincter** The circular layer of smooth muscle at the junction of the esophagus and stomach; contracts to prevent reflux of stomach contents into the esophagus.
- Cartilage** (kar'ti-lij) White, semiopaque, resilient connective tissue; gristle.
- Caudal** (kaw'dal) Literally, toward the tail; in humans, toward the inferior portion of the trunk.
- Cecum** (se'kum) The blind-ended pouch at the beginning of the large intestine.
- Cell membrane** *See* Plasma membrane.
- Central nervous system (CNS)** Brain and spinal cord.
- Centriole** (sen'tre-ol) Barrel-shaped organelle formed of microtubules and located near the nucleus of the cell; active in cell division.
- Cerebellum** (ser"ě-bel'um) Brain region that is attached to the pons and smooths and coordinates body movements.
- Cerebral aqueduct** (sě-re'bral ak'wě-dukt") The narrow cavity of the midbrain that connects the third and fourth ventricles.
- Cerebral arterial circle** A union of arteries at the base of the brain; also called *circle of Willis*.
- Cerebral cortex** The external, gray matter region of the cerebral hemispheres.
- Cerebrospinal fluid (CSF)** (ser"ě-bro-spi'nal) Clear fluid that fills the cavities of the central nervous system and surrounds the CNS externally; it floats and cushions the brain and spinal cord.
- Cerebrum** (ser'ě-brum) The cerebral hemispheres (some authorities also include the diencephalon).
- Cervix** (ser'viks) The inferior, necklike part of the uterus (*cervix* = neck).
- Chemoreceptor** (ke"mo-re-sep'tor) Receptor sensitive to chemicals in solution.
- Cholesterol** (ko-les'ter-ol) A steroid lipid found in animal fats as well as in the plasma membranes of cells.
- Chondroblast** (kon'dro-blast) Actively mitotic form of a cartilage cell.
- Chondrocyte** (kon'dro-sīt) Mature form of a cartilage cell.
- Chorion** (ko're-on) The outermost fetal membrane; helps form the placenta; technically, it consists of the trophoblast and the extraembryonic mesoderm.
- Choroid plexus** (ko'roid) A capillary-rich membrane on the roof of the brain that forms the cerebrospinal fluid; technically, it consists of pia mater and ependymal cells.
- Chromatin** (kro'mah-tin) Strands in the cell nucleus that consist of deoxyribonucleic acid (DNA) and histone proteins.
- Chromosome** (kro'mo-sōm) Barlike body of tightly coiled chromatin, visible during cell division; typical human cells have 46 chromosomes.
- Chronic** (kron'ik) Long-term; prolonged; not acute.
- Chyme** (kīm) Semifluid, creamy mass consisting of partially digested food and stomach juices.
- Cilium** (sil'e-um) Motile, hairlike projection from the apical surface of certain epithelial cells.
- Circumduction** (ser"kum-duk'shun) Movement of a body part so that it outlines a cone in space.
- Cirrhosis** (si-ro'sis) A chronic disease, particularly of the liver, characterized by an overgrowth of connective tissue, or fibrosis.
- Cleavage** An early embryonic stage consisting of rapid cell divisions without intervening growth periods; begins with a fertilized ovum and produces a blastocyst.
- Cochlea** (kok'le-ah) Snail-shaped chamber of the bony labyrinth in the internal ear; houses the receptor for hearing (spiral organ of Corti).
- Cognition** (kog-nish'un) All aspects of thinking, perceiving, and intentionally remembering and recalling information; the mental processes involved in obtaining knowledge.
- Collagen fibers** The strongest and most abundant fibrous component of connective tissues; composed of fibrils arranged in bundles. Has high tensile strength.
- Collateral ganglia** Ganglia of the sympathetic nervous system that are not part of the sympathetic trunk. Located anterior to the vertebral column (thus also called *prevertebral ganglia*) in the abdomen and pelvis; includes the celiac, superior mesenteric, inferior mesenteric, and inferior hypogastric ganglia. Contain ganglionic neurons that innervate the abdominopelvic organs.
- Commissure** A bundle of axons that crosses from one side of the central nervous system to the other.
- Condyle** (kon'dīl) A rounded projection at the end of a bone that articulates with another bone.
- Cone cell** One of the two types of photoreceptor cells in the retina of the eye; provides for color vision and sharp vision.
- Congenital** (kon-jen'i-tal) Existing at birth.
- Conjunctiva** (kon"junk-ti'vah) Thin, protective mucous membrane that covers the white of the eye and the internal surface of eyelids.
- Connective tissue** A primary tissue; form and function vary widely, but all connective tissues contain a large amount of extracellular matrix; functions include support, holding tissue fluid, and protection from disease.
- Constriction** Narrowing of a blood or lymphatic vessel, or of an opening like the pupil. Often caused by the squeezing action of circular musculature. *See* Dilation.
- Contraction** The generation of a pulling force while shortening; this ability is highly developed in muscle cells.
- Contralateral** (kon"trah-lat'er-al) Concerning the opposite half of the body; when nerve fibers project contralaterally, they cross over to the opposite side of the body (right to left, or vice versa).
- Cornea** (kor'ne-ah) Transparent anterior portion of the eyeball.
- Corona radiata** (kō-ro'nah ra-de-ah'tah) (1) Crownlike arrangement of granulosa cells around an oocyte in an ovarian follicle after the appearance of an antrum; (2) crownlike arrangement of nerve fibers in the white matter of the cerebrum, radiating to and from every part of the cerebral cortex.
- Coronal plane** (kō-ro'nal) *See* Frontal plane.
- Cortex** (kor'teks) Outer region of an organ.
- Corticosteroids** (kor"ti-ko-ste'roids) Steroid hormones secreted by the adrenal cortex. Examples are cortisol, aldosterone, and some sex hormones.
- Cortisol** (kor'ti-sol) A glucocorticoid hormone produced by the adrenal cortex.
- Cranial nerves** The 12 pairs of nerves that attach to the brain.
- Cutaneous** (ku-ta'ne-us) Pertaining to the skin.
- Cytokinesis** (si"to-ki-ne'sis) Division of the cytoplasm that occurs after the cell nucleus has divided.
- Cytoplasm** (si'to-plazm) The part of a cell between the plasma membrane and the nucleus; contains many organelles.
- Cytotoxic (CD8⁺) T lymphocyte** T lymphocyte that directly kills eukaryotic foreign cells, cancer cells, or virus-infected body cells; also called *killer T cell*.
- Decussation** A crossing of structures in the form of an X. Often applied to axons that cross the body midline from the left to the right side (or vice versa) of the central nervous system.
- Deep** Toward the inside; inner; internal.
- Defecation** (def'ě-ka-shun) Elimination of the contents (feces) of the bowel.
- Dendrite** (den'drīt) Neuron process that transmits signals toward the cell body and serves as receptive region of the neuron; most dendrites branch extensively.

Deoxyribonucleic acid (DNA) (de-ok"ŝi-ri"bo-nu-kle'ik) A nucleic acid found in all living cells; carries the organism's hereditary information.

Dermis The leathery layer of skin, deep to the epidermis; composed largely of dense irregular connective tissue.

Desmosome (des'mo-sōm) A cell junction composed of two disc-shaped plaques connected across the intercellular space; the most important junction for holding epithelial cells together.

Diabetes insipidus (di"ah-be'tēz) Disease characterized by passage of a large quantity of dilute urine plus intense thirst and dehydration; caused by inadequate release of antidiuretic hormone.

Diabetes mellitus Disease caused by deficient release of, or deficient use of, insulin; characterized by an inability of the body cells to use sugars at a normal rate and by high blood sugar levels.

Diapedesis (di"ah-pē-de'sis) Active movement of white blood cells through the walls of capillaries and venules into the surrounding tissue.

Diaphragm (di'ah-fram) (1) Any partition or wall separating one area from another; (2) the muscular sheet that separates the thoracic cavity from the abdominopelvic cavity.

Diaphysis (di-af'ī-sis) Elongated shaft of a long bone.

Diarthrosis (di"ar-thro'sis) Freely movable joint; all synovial joints are diarthroses.

Diastole (di-as'to-le) Period during which the ventricles or atria of the heart relax.

Diencephalon (di'en-sef'ah-lon) The part of the forebrain between the cerebral hemispheres and the midbrain; includes the thalamus, hypothalamus, and third ventricle.

Diffusion (dī-fu'zhun) The spreading of particles in a gas or solution from regions of high particle concentration to regions of low concentration, with movement toward a uniform distribution of the particles.

Digestion Chemical and mechanical process of breaking down foodstuffs into molecules that can be absorbed.

Dilation Expansion or widening of a vessel, organ, or opening. (*See* Constriction.)

Distal (dis'tal) Away from the attached end of a structure, especially a limb.

Diverticulum (di'ver-tik'u-lum) A pouch or a sac in the walls of a hollow organ or structure.

Dorsal (dor'sal) Pertaining to the back; posterior.

Duct Canal or passageway, usually tubular.

Ductus (vas) deferens (def'er-ens) Extends from the epididymis to the urethra; propels sperm into the urethra via peristalsis during ejaculation.

Duodenum (du"o-de-num) First part of the small intestine.

Dura mater (du'rah ma'ter) Most external and toughest of the three membranes (meninges) covering the brain and spinal cord.

Ectoderm (ek'to-derm) Embryonic germ layer that forms both the outer layer of the skin (epidermis) and nervous tissues.

Edema (ē-de'mah) Abnormal accumulation of tissue fluid in the loose connective tissue; causes the affected body region to swell.

Effector (ef-fek'tor) Muscle or gland capable of being activated by motor nerve endings.

Efferent (ef'er-ent) Carrying away or away from, especially a nerve fiber that carries impulses away from the central nervous system; efferent neurons are motor neurons.

Elastin (e-las'tin) Main protein in elastic fibers of connective tissues; stretchable and resilient.

Embolus (embolism) (em'bo-lus) Any abnormal mass carried freely in the bloodstream; maybe a blood clot, bubbles of air, mass of fat, or clumps of cells.

Embryo (em'bre-o) The developing human from week 2 through week 8 after fertilization.

Endocarditis (en"do-kar-di'tis) Inflammation of the inner lining of the heart.

Endocardium (en"do-kar'de-um) The layer that lines the inner surface of the heart wall; consists of endothelium and areolar connective tissue.

Endocrine glands (en'do-krin) Ductless glands that secrete hormones into the blood.

Endocrine system Body system consisting of glands that secrete hormones.

Endocytosis (en"do-si-to'sis) Processes by which large molecules and particles enter cells; types are phagocytosis, pinocytosis, and receptor-mediated endocytosis.

Endoderm (en'do-derm) An embryonic germ layer that forms the lining and glands of the digestive and respiratory tubes.

Endometrium (en"do-me'tre-um) Mucous membrane lining the uterus.

Endomysium (en"do-mis'e-um) Thin connective tissue surrounding each muscle cell.

Endoplasmic reticulum (ER) (en"do-plaz'mik rē-tik'u-lum) A system of membranous envelopes and tubes in the cytoplasm of a cell; there are smooth and rough varieties.

Endosteum (en-dos'te-um) Layer of cells lining the internal surfaces of bone, specifically, lining the central canals of osteons and the medullary cavity, and covering the trabeculae of spongy bone.

Endothelium (en"do-the'le-um) The simple squamous epithelium that lines the walls of the heart, blood vessels, and lymphatic vessels.

Enzyme (en'zīm) A protein that acts as a biological catalyst to speed up chemical reactions.

Eosinophil (e'o-sin'o-fil) Granular white blood cell whose granules readily take up a pink dye called eosin; helps end allergy reaction and fights parasites.

Epidermis (ep'ī-der'mis) Superficial layer of the skin, composed of a keratinized stratified squamous epithelium.

Epididymis (ep'ī-did'ī-mis) Comma-shaped structure in the scrotum adjacent to the testis; contains a duct in which the sperm mature.

Epiglottis (ep'ī-glōt'is) A leaf-shaped piece of elastic cartilage that extends from the posterior surface of the tongue to the larynx; covers the opening of the larynx during swallowing.

Epimysium (ep'ī-mis'e-um) Sheath of fibrous connective tissue surrounding a muscle.

Epinephrine (ep'ī-nef'rīn) Chief hormone produced by the adrenal medulla; also called *adrenaline*.

Epiphyseal plate (ep'ī-fiz'e-al) Plate of hyaline cartilage at the junction of the diaphysis (shaft) and epiphysis (end) of most bones in the growing skeleton; provides growth in the length of the bone.

Epiphysis (e-pif'ī-sis) The end of a long bone, attached to the shaft.

Epithelium (ep'ī-the'le-um) A primary tissue that covers body surfaces and lines body cavities; its cells are arranged in sheets; also forms glands.

Equilibrium The sense of balance; measures both the position and the movement of the head.

Erythrocyte (ē-rith'ro-sīt) Red blood cell; when mature, an erythrocyte is literally a sac of hemoglobin (oxygen-carrying protein) covered by a plasma membrane.

Estrogens (es'tro-jens) Female sex hormones.

Exocrine glands (ek'so-krin) Glands that secrete onto body surfaces or into body cavities; except for the one-celled goblet cells, all exocrine glands have ducts.

Exocytosis (ek"so-si-to'sis) Mechanism by which substances are moved from the cell interior to the extracellular space; the main mechanism of secretion.

Expiration Act of expelling air from the lungs; exhalation.

Exteroceptor (ek"ster-o-sep'tor) Sensory end organ that responds to stimuli from the external world.

Extracellular Outside a cell.

Extracellular matrix (ma'triks) The material that lies between the cells in connective tissues; consists of fibers, ground substance, and tissue fluid.

Extrinsic (ek-strin'sik) Originating outside an organ or part.

Facet (fas'et) A smooth, nearly flat surface on a bone for articulation.

Fallopian tube (fah-lo'pe-an) *See* Uterine tube.

Fascia (fash'e-ah) Layers of fibrous connective tissue that cover and separate muscles and other structures. Superficial fascia is the fatty hypodermis of the skin.

Fascicle (fas'i-k'l) Bundle of nerve or muscle fibers bound together by connective tissue.

Fenestrated (fen'es-tra-ted) Pierced with one or more small openings or pores.

Fertilization Fusion of the sperm and egg nuclei.

Fetus (fe'tus) Developmental stage lasting from week 9 of development to birth.

Fibroblast (fi'bro-blast) Young, actively mitotic cell that secretes the fibers and ground substance of connective tissue proper.

Fibrocyte (fi'bro-sit) Mature fibroblast; maintains the matrix of connective tissue proper.

Filtration Passage of a solution or suspension through a membrane or filter, with the purpose of holding back the larger particles.

Fissure (fish'er) (1) A groove or cleft; (2) the deepest depressions or inward folds on the brain.

Fixator (fik-sa'tor) Muscle that immobilizes one or more bones, allowing other muscles to act from a stable base.

Flagellum (flah-jel'um) Long, whiplike extension of the plasma membrane of some bacteria and sperm cells; propels the cell.

Follicle (fol'i-k'l) (1) Spherical structure in the ovary consisting of a developing egg cell surrounded by one or more layers of follicle cells; (2) colloid-containing structure in the thyroid gland.

Follicle-stimulating hormone (FSH) Hormone secreted by the anterior pituitary that stimulates the maturation of ovarian follicles in females and the production of sperm in males.

Foramen (fo-ra'men) Hole or opening in a bone or between body cavities.

Forebrain Rostral portion of the brain, consisting of the telencephalon and diencephalon.

Formed elements Blood cells (red and white cells and platelets).

Fossa (fos'ah) A depression, often a joint surface.

Fovea (fo've-ah) A pit.

Frontal (coronal) plane Vertical plane that divides the body into anterior and posterior parts.

Fundus (fun'dus) The base of an organ; that part farthest from the opening of an organ.

Funiculus (fu-nik'u-lus) (1) A cordlike structure; (2) a division of the white matter in the spinal cord.

Gallbladder Sac inferior to the right part of the liver; it stores and concentrates bile.

Gamete (gam'et) Sex cell; sperm or oocyte.

Gametogenesis (gam'et-to-jen'et-sis) Formation of gametes.

Ganglion (gang'gle-on; plural, *ganglia*) Collection of neuron cell bodies outside the central nervous system.

Gap junction A passageway between two adjacent cells; formed by transmembrane proteins called connexons.

Gene One of the biological units of heredity located in chromatin; transmits hereditary information; roughly speaking, one gene codes for the manufacture of one protein.

General Pertaining to sensory inputs or motor outputs that are *widely distributed* through the body rather than localized; opposite of *special*.

Germ layers Three cellular layers (ectoderm, mesoderm, and endoderm) that represent the early specialization of cells in the embryonic body and from which all body tissues arise.

Gestation (jes-ta'shun) The period of pregnancy; averages 280 days in humans.

Gland A structure whose cells are specialized for secretion.

Glial cells (gle'al) *See* Neuroglia.

Glomerular capsule (glo-mer'u-lar) Double-walled cup forming the initial portion of the nephron in the kidney; also called *Bowman's capsule*.

Glomerulus (glo-mer'u-lus) (1) A ball of capillaries forming part of the nephron in the kidney; forms a filtrate that will be modified into urine. (2) A cluster of complex synapses within the olfactory bulb between the axonal branches of the olfactory nerve and a dendritic process of a mitral cell.

Glottis (glot'is) The opening between the two vocal cords in the larynx.

Glucagon (gloo'kah-gon) Hormone secreted by alpha cells of the pancreatic islets; raises the glucose level of blood.

Glucocorticoids (gloo'ko-kor'ti-koids) Hormones secreted by the cortex of the adrenal gland; they increase the concentration of glucose in the blood and aid the body in resisting long-term stress.

Glucose (gloo'kös) The principal blood sugar; the main sugar used by cells for energy.

Glycogen (gli'ko-jen) A long chain of glucose molecules; the main form in which sugar is stored in animal cells; glycogen takes the form of dense granules in the cytoplasm.

Goblet cells Individual mucus-secreting cells of the respiratory and digestive tracts.

Gonad (go'nad) Primary reproductive organ: the testis of the male or the ovary of the female.

Gonadotropins (go-nad'o-tröp'ins) Gonad-stimulating hormones secreted by the anterior pituitary: follicle-stimulating hormone and luteinizing hormone.

Gray matter Gray area of the central nervous system; contains neuron cell bodies and unmyelinated processes of neurons.

Ground substance The nonfiber part of the extracellular matrix of connective tissue. In many connective tissues it is a gel-like substance with large molecules that attract water and hold tissue fluid; in bone it is hard.

Growth hormone Hormone that stimulates growth of the body; secreted by the anterior pituitary; also called somatotropin and somatotrophic hormone (SH).

Gustation (gus-ta'shun) Taste.

Gyrus (ji-rus) A ridge on the surface of the cerebral cortex.

Hair follicle Tubelike invagination of the epidermis of the skin from which a hair grows.

Haustra (hos'trah) Pouches (sacculations) of the colon.

Heart block Impaired transmission of impulses from atria to ventricles.

Heart murmur Abnormal heart sound (usually resulting from valve problems).

Helper (CD4⁺) T cell A type of T lymphocyte that participates in the activation of other lymphocytes by secreting chemicals that stimulate newly activated lymphocytes to multiply.

Hematocrit (he-mat'o-krit) The percentage of total blood volume occupied by erythrocytes.

Hematoma (he'mah-to'mah) A mass of blood that has bled from blood vessels into the tissues.

Hematopoiesis (hem'ah-to-poi-e'sis) Blood cell formation; hemopoiesis.

Hemoglobin (he'mo-glo'bin) Oxygen-transporting protein in erythrocytes.

Hemopoiesis *See* Hematopoiesis.

Hemorrhage (hem'ö-rij) Bleeding.

Hepatic portal system (hē-pat'ik) The part of the circulation in which veins receive nutrients from capillaries in the stomach and intestines and carry these nutrients to capillaries in the liver; the liver cells then process the nutrients.

Hepatitis (hep'ah-ti'tis) Inflammation of the liver.

Hernia (her'ne-ah) Abnormal protrusion of an organ or body part through the containing wall of its cavity.

Hilum (hi'lum) A slit on the surface of an organ through which the vessels and nerves enter and leave; the spleen, lungs, kidneys, lymph nodes, and ovaries have prominent hilums.

Histamine (his'tah-mēn) Chemical substance that increases vascular permeability in the initial stages of inflammation.

Histology (his-tol'o-je) Branch of anatomy dealing with the microscopic structure of tissues, cells, and organs.

Holocrine gland (hol'o-krin) A gland in which entire cells break up to form the secretion product; sebaceous (oil) glands of the skin are the only example.

Hormones Messenger molecules that are released by endocrine glands and travel in the blood to regulate specific body functions.

Hypertension (hi'per-ten'shun) High blood pressure.

Hypertrophy (hi-per'tro-fe) Enlargement of an organ or tissue due to an increase in the size of its cells.

Hypodermis (hi'po-der'mis) The fatty layer deep to the skin; consists of adipose and areolar connective tissue; also called the *subcutaneous layer* and *superficial fascia*.

Hypophysis (hi-pof'ī-sis) The pituitary gland.

Hypothalamus (hi'po-thal'ah-mus) Inferior region of the diencephalon; visceral control center of the brain.

Ileum (il'e-um) Coiled terminal part of the small intestine, located between the jejunum and the cecum of the large intestine.

Immune system Organ system consisting of lymphocytes (T and B cells), lymphoid tissues, and lymphoid organs (lymph nodes, spleen, thymus, tonsils, and aggregated lymphoid nodules in the small intestine and appendix); responsible for antigen-specific defenses mounted by activated lymphocytes.

Immunity (ī-mu'nī-te) Ability of the body to develop resistance to specific foreign agents (both living and nonliving) that can cause disease.

Immunocompetence Ability of the body's immune system to recognize specific antigens.

Induction (in-dŭk'shun) The influence exerted by a group of cells on the differentiation of adjacent cells or on the development of an embryonic structure.

Inferior (caudal) Below; toward the feet.

Inflammation (in'flah-ma'shun) A physiological response of the body to tissue injury; includes dilation of blood vessels and an increase in capillary permeability; indicated by redness, heat, swelling, and pain in the affected area.

Inguinal (ing'gwī-nal) Pertaining to the groin region.

Inner cell mass Accumulation of cells in the blastocyst from which the body of the embryo derives.

Innervation (in'er-va'shun) Supply of nerves to a body part.

Insertion Movable part or attachment of a muscle, as opposed to the muscle's origin.

Inspiration Drawing of air into the lungs; inhalation.

Insulin (in'su-lin) Hormone secreted by beta cells in pancreatic islets; it decreases blood glucose levels.

Integumentary system (in-teg'u-men'tar-e) The skin and its appendages (hairs, nails, and skin glands).

Intercalated discs (in-ter'kah-la'ted) Complex junctions that interconnect cardiac muscle cells in the wall of the heart.

Intercellular Between body cells.

Internal Deep to.

Internal capsule Band of white matter in the brain, between the basal ganglia and the thalamus.

Internal respiration Exchange of gases between blood and tissue fluid and between tissue fluid and cells.

Interneuron (in'ter-nu'ron) (1) Nerve cell that lies between a sensory neuron and a motor neuron in a reflex arc; (2) any nerve cell that is confined entirely within the central nervous system.

Interoceptor (in'ter-o-sep'tor) Nerve ending situated in a visceral organ; responds to changes and stimuli within the body's internal environment; also called *visceroceptor*.

Interstitial fluid (in'ter-stish'al) *See* Tissue fluid.

Intervertebral discs (in'ter-ver'tē-bral) The discs between the vertebrae of the spinal column; each consists of fibrous rings surrounding a springy core.

Intervertebral foramina (fo-ra'min-ah) Openings between the dorsal projections of adjacent vertebrae through which the spinal nerves pass.

Intracellular Within a cell.

Intraperitoneal Within the peritoneal cavity.

Invaginate To form an inpocketing or to grow inward. For example, an epithelium pushes inward, pocketlike, into the underlying connective tissue to form a gland during development.

Ion (i'on) Atom or molecule with a positive or negative electrical charge.

Ipsilateral (ip'sī-lat'er-al) Situated on the same side of the body; opposite of *contralateral*.

Ischemia (is-ke'me-ah) Local decrease in blood supply.

Jejunum (jē-joo'num) The coiled part of the small intestine that is located between the duodenum and ileum.

Joint Junction of two or more elements of the skeleton; an articulation.

Keratin (ker'ah-tin) Tension-resisting protein found in the epidermis, hair, and nails; keratin makes these structures tough and able to resist friction.

Labium (la'be-um) Lip.

Labyrinth (lab'ī-rinth) Bony cavities and membranes of the inner ear.

Lacrimal (lak'rī-mal) Pertaining to tears.

Lactation (lak-ta'shun) Production and secretion of milk.

Lacteal (lak'te-al) Lymphatic capillaries in the small intestine that take up lipids.

Lacuna (lah-ku'nah) Little depression or cavity; in bone and cartilage, each lacuna is occupied by a cell.

Lamina (lam'ī-nah) (1) A thin layer or flat plate; (2) the portion of a vertebra between the transverse process and the spinous process.

Laparoscopy (lap'ah-ros'ko-pe; "observing the flank") Examination of the peritoneal cavity and the associated organs with a laparoscope, a viewing device (endoscope) at the end of a thin tube that is inserted through the abdominal wall.

Larynx (lar'ingks) Cartilaginous organ located between the pharynx and trachea; contains the vocal cords; the voice box.

Lateral Away from the body midline.

Leukocyte (loo'ko-sīt) White blood cell; the five types of leukocytes are all involved in the defense against disease.

Ligament (lig'ah-ment) Band of dense regular connective tissue that connects bones.

Limbic system (lim'bik) A functional brain system involved in emotional and visceral responses; structurally, it includes medial portions of the cerebral cortex (septal nuclei, cingulate gyrus, hippocampal formation, and amygdala), the fornix, and parts of the diencephalon (hypothalamus and anterior thalamic nuclei).

Lumbar (lum'bar) Region of the back between the thorax and the pelvis.

Lumen (lu'men) The cavity inside a tube, blood vessel, or hollow organ.

Luteinizing hormone (LH) (loo'te-in-īz'ing) A hormone secreted by the anterior pituitary; in females, it aids maturation of follicles in the ovary and triggers ovulation; in males, it signals the interstitial cells of the testis to secrete testosterone.

Lymph (limf) The clear fluid transported by the lymphatic vessels.

Lymph node Bean-shaped lymphoid organ that filters and cleanses the lymph.

Lymphatic system (lim-fat'ik) Organ system consisting of lymphatic vessels, lymph nodes, and the lymphoid organs and tissues; drains excess tissue fluid and fights disease.

Lymphatics General term used to designate lymphatic vessels.

Lymphocyte (lim'fo-sīt) Agranular white blood cell that arises from bone marrow and becomes functionally activated in the lymphoid organs of the body; the main cell type of the immune system; each lymphocyte recognizes a specific antigen.

Lymphoid organs The organs of the lymphatic system that house lymphocytes and function in immunity; spleen, lymph nodes, tonsils, and thymus are the main examples.

Lymphoid tissue The main tissue of the immune system; a reticular connective tissue that houses and activates many lymphocytes.

- Lyse** (līz) To break up or disintegrate.
- Lysosome** (li'so-sōm) A membrane-bound, saclike cytoplasmic organelle that contains a wide variety of digestive enzymes.
- Macrophages** (mak'ro-fāj-es) The general phagocytic cells of the body, capable of engulfing and digesting a wide variety of foreign cells, particles, and molecules; present throughout the connective tissues of the body and especially abundant in lymphoid tissues of the immune system.
- Malignant** (mah-lig'nant) Life-threatening; pertains to neoplasms such as cancer that spread and lead to death.
- Mammary glands** (mam'ar-e) The breasts.
- Mast cell** A connective tissue cell containing secretory granules that initiate and mediate local inflammatory responses.
- Mastication** (mas'tī-ka'shun) Chewing.
- Meatus** (me-a'tus) A canal or opening.
- Mechanoreceptor** (mek'ah-no-re-sep'tor) Receptor sensitive to mechanical forces, such as touch, stretch, pressure, or vibration.
- Medial** Toward the midline of the body.
- Median** (me'de-an) In the midline of the body; midsagittal.
- Mediastinum** (me'de-ah-sti'num) Region of the thoracic cavity between the lungs; contains the heart, thoracic aorta, esophagus, and other structures.
- Medulla** (me-dul'ah) Middle or internal region of certain organs.
- Medulla oblongata** (ob'long-gah'tah) Inferior part of the brain stem.
- Meiosis** (mi-o'sis) A process of nuclear division that occurs during the production of the sex cells and reduces the chromosome number by half; results in the formation of haploid (*n*) cells.
- Melanin** (mel'ah-nin) Dark pigment formed by cells called melanocytes; imparts color to the skin and hair.
- Memory lymphocytes** T and B lymphocytes that provide for immunological memory (acquired, long-term immunity from diseases).
- Meninges** (mě-nin'jēz) Protective coverings around the brain and spinal cord; from external to internal, they are the dura mater, arachnoid mater, and pia mater.
- Meningitis** (men'in-jī'tis) Inflammation of the meninges.
- Menstrual cycle** (men'stroo-al) The changes in the female reproductive organs that occur every month (28 days, on the average).
- Menstruation** (men'stroo-a'shun) Menstrual phase of the uterine cycle; the periodic, cyclic discharge of blood and tissue from the lining of the female uterus in the absence of pregnancy.
- Mesencephalon** (mes'en-sef'ah-lon) Midbrain.
- Mesenchyme** (mes'eng-kīm) The type of embryonic tissue from which connective tissues and muscle tissues arise.
- Mesenteries** (mes'en-ter'ēz) Double-layered sheets of peritoneum that support most organs in the abdominopelvic cavity.
- Mesoderm** (mez'o-derm) The embryonic germ layer that gives rise to most structures in the body, including the skeleton, muscles, dermis, connective tissues, kidneys, and gonads.
- Metabolic rate** (mě-tah-bol'ik) Energy expended by the body per unit time.
- Metabolism** (mě-tab'o-lizm) Sum total of all the chemical reactions occurring in the cells of the body.
- Metastasis** (mě-tas'tah-sis) The spread of cancer from one body part or organ to another not directly connected to it.
- Microvilli** (mi'kro-vil'i) Immobile, cellular projections on the free surface of most epithelia; microvilli anchor sheets of mucus or increase surface area for absorption.
- Micturition** (mik'tu-rish'un) Urination, or voiding; emptying the bladder.
- Midbrain** Region of the brain stem that lies between the diencephalon and the pons.
- Mineralocorticoids** (min'er-al-o-kor'tī-koids) Steroid hormones secreted by the adrenal cortex that increase the resorption of sodium and water by the kidneys; the main mineralocorticoid is aldosterone.
- Mitochondrion** (mi'to-kon'dre-on) Cytoplasmic organelle that generates most adenosine triphosphate (ATP) for cellular activities; mitochondria are the cell's "power plants."
- Mitosis** (mi-to'sis) Division of the nucleus during the typical process of cell division, during which the chromosomes are distributed to the two daughter nuclei.
- Mitral valve** The valve on the left side of the heart between the left atrium and left ventricle. Also called the *bicuspid valve*.
- Mixed nerve** A nerve containing fibers of both sensory and motor neurons; most nerves are mixed nerves.
- Monocyte** (mon'o-sīt) An agranular white blood cell, with a large nucleus that is often bent into the shape of a C; the largest of all blood cells; develops into a macrophage.
- Motor neuron** Nerve cell that signals muscle cells to contract or gland cells to secrete; also called *efferent neuron*.
- Motor unit** A motor neuron and all of the muscle cells it stimulates.
- Mucosa** (mu-ko'sah) See Mucous membranes.
- Mucous membranes** Moist membranes that line all tubular organs and body cavities that open to the exterior (digestive, respiratory, urinary, and reproductive tracts).
- Mucus** (mu'kus) A sticky, viscous fluid that covers many internal surfaces in the body; it consists of the protein mucin and a large amount of water.
- Multipolar neuron** (mul'tī-po'lar) A nerve cell that has more than two processes; most neurons are multipolar, having several dendrites and an axon.
- Muscle fiber** Muscle cell.
- Muscle spindle** Complex, spindle-shaped receptor in skeletal muscles that senses muscle stretch.
- Muscle tone** Continuous, low levels of contractile force produced by muscles that are not actively shortening.
- Myelencephalon** (mi'el-en-sef'ah-lon) Caudal part of the hindbrain; the medulla oblongata.
- Myelin sheath** (mi'ē-lin) Fatty insulating sheath that surrounds all but the thinnest nerve fibers; formed of the plasma membrane of neuroglia wrapped in concentric layers around the nerve fiber.
- Myocardial infarction** (mi'o-kar'de-al) Condition characterized by dead tissue areas in the myocardium of the heart; caused by interruption of blood supply to the area; also called *heart attack*.
- Myocardium** (mi'o-kar'de-um) Layer of the heart wall composed of cardiac muscle.
- Myofibril** (mi'o-fi'bril) Rodlike bundle of contractile myofilaments in the cytoplasm of a skeletal muscle cell; made of repeating segments called sarcomeres.
- Myofilament** (mi'o-fil'ah-ment) The contractile filaments in muscle cells; the two varieties are thick (myosin) filaments and thin (actin) filaments.
- Myometrium** (mi'o-me'tre-um) The thick layer of smooth muscle in the wall of the uterus.
- Myosin** (mi'o-sin) A contractile protein in cells, especially abundant in muscle cells.
- Nares** (na'rēz) The nostrils.
- Necrosis** (ně-kro'sis) Death of a cell or tissue caused by disease or injury.
- Neoplasm** (ne'o-plazm) See Tumor.
- Nephron** (nef'ron) A major division of the uriniferous tubule in the kidney (the other division is the collecting duct).
- Nerve** A collection of nerve fibers (long axons) in the peripheral nervous system.
- Nerve fiber** Any long axon of a neuron.
- Nerve impulse** See action potential.
- Neural crest** Embryonic tissue derived from ectoderm that migrates widely within the embryo and gives rise to sensory neurons, all nerve ganglia, melanocytes, and other structures.
- Neuroglia** (nu-rog'le-ah) Nonexcitable cells of neural tissue that support, protect, and insulate neurons; glial cells.
- Neurohypophysis** (nu'ro-hi-pof'i-sis) The part of the pituitary gland that derives from the brain; contains the stalklike infundibulum and the posterior lobe of the pituitary.

Neuromuscular junction Location where the axon terminal of a motor neuron meets a skeletal muscle fiber; this junction transmits the stimulus to contract from the neuron to the muscle fiber.

Neuron (nu'ron) Cell of the nervous system specialized to generate and transmit electrical signals; a nerve cell.

Neurotransmitter (nu"ro-trans'mit-er) Chemical released by neurons that may, upon binding to receptors on neurons or effector cells, stimulate or inhibit them.

Neutrophil (nu'tro-fil) Most abundant type of white blood cell; a granulocyte specialized for destroying bacteria.

Nucleic acid (nu-kle'ik) The class of organic molecules that includes deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

Nucleolus (nu-kle'o-lus) A small, dark-staining body in the cell nucleus; represents parts of several chromosomes and manufactures the basic subunits of ribosomes.

Nucleus (nu'kle-us) (1) Control center of a cell; contains genetic material; (2) a cluster of neuron cell bodies in the brain.

Occipital (ok-sip'i-tal) Pertaining to the area at the back of the head.

Occlusion (ö-kloo'zhun) Closure or obstruction.

Olfaction (ol-fak'shun) Smell.

Olfactory epithelium (ol-fak'to-re) A sensory receptor region in the superior lining of the nasal cavity; this epithelium contains olfactory neurons that respond to odors in the air.

Oocyte (o'o-sit) Immature egg undergoing the process of meiosis.

Oogenesis (o"o-jen'ě-sis) Process of ovum (female gamete) formation.

Ophthalmic (of-thal'mik) Pertaining to the eye.

Optic (op'tik) Pertaining to the eye.

Optic chiasma (ki-az'mah) A cross-shaped structure anterior to the diencephalon of the brain, representing the point of crossover of half the axons of the optic nerve.

Organ A part of the body formed of two or more tissues and adapted to carry out a specific function; the stomach and biceps brachii muscle are examples of large organs, but many organs are smaller and simpler (sweat gland, hair follicle, muscle spindle).

Organ system A group of organs that work together to perform a vital body function; e.g., the nervous system.

Organelles (or'gah-nelz') Small structures in the cytoplasm (ribosomes, mitochondria, and others) that perform specific functions for the cell. Nucleus is also an organelle.

Origin Attachment of a muscle that remains relatively fixed during muscular contraction.

Osmosis (oz-mo'sis) Diffusion of a solvent (water molecules) through a membrane from a dilute solution into a more concentrated one.

Ossification (os"i-fī-ka'shun) Bone formation. *See* Osteogenesis.

Osteoblast (os'te-o-blast") A bone-forming cell.

Osteoclast (os'te-o-klast") Large cell that reabsorbs or breaks down the bone matrix.

Osteocyte (os'te-o-sīt") Mature bone cell, shaped like a spider with a body and long processes, that occupies a lacuna in the bone matrix.

Osteogenesis (os'te-o-jen'ě-sis) Process of bone formation.

Osteon (os'te-on) Tube-shaped unit in mature, compact bone; consists of concentric layers of bone lamellae surrounding a central canal; also called *Haversian system*.

Osteoporosis (os'te-o-po-ro'sis) Age-related condition (affects many elderly women) in which bones weaken as bone reabsorption outpaces bone deposition; the weakened bones break easily.

Ovarian cycle (o-va're-an) Monthly cycle of follicle development in the ovaries, ovulation, and formation of the corpus luteum; the menstrual cycle as it involves the ovaries.

Ovary (o'var-e) Female sex organ in which ova (eggs) are produced; the female gonad in the pelvis.

Ovulation (o"vu-la'shun) Ejection of an egg (oocyte) from the ovary.

Ovum (o'vum) (1) General meaning: the female germ cell, or egg; (2) specific meaning: female germ cell after a sperm has entered it but before the sperm nucleus and the egg nucleus have fused.

Oxytocin (ok"si-to'sin) Hormone produced by the hypothalamus and released by the posterior pituitary; it stimulates contraction of the uterus during childbirth and the ejection of milk during nursing.

Palate (pal'at) Roof of the mouth.

Palpation (pal-pa'shun) Using one's fingers to feel deep organs through the skin of the body surface.

Pancreas (pan'kre-as) Tadpole-shaped gland posterior to the stomach; produces both exocrine and endocrine secretions.

Pancreatic juice Bicarbonate-rich secretion of the pancreas containing enzymes for digestion of all food categories.

Parasympathetic (par"ah-sim"pah-thet'ik) The division of the autonomic nervous system that oversees digestion, elimination, and glandular function; the resting and digesting division.

Parathyroid glands (par"ah-thi'roid) Small endocrine glands located on the posterior aspect of the thyroid gland.

Parathyroid hormone (PTH) Hormone secreted by the parathyroid glands; it increases the concentration of calcium ions in the blood.

Paresthesia An abnormal sensation of numbness, burning, or tingling.

Parietal (pah-ri'ě-tal) Pertaining to the walls of a cavity.

Pars distalis (parz dis-tal'is) The main division of the adenohypophysis of the pituitary gland; the anterior lobe of the pituitary.

Pars nervosa (ner-vo'sah) The region of the neurohypophysis of the pituitary gland from which hormones are secreted; the posterior lobe of the pituitary.

Pectoral (pek'tor-al) Pertaining to the chest.

Pectoral girdle Bones that attach an upper limb to the axial skeleton: clavicle and scapula.

Pelvic girdle The paired hip bones that attach the lower limbs to the axial skeleton.

Pelvis (pel'vis) Inferior region of the body trunk; contains the basin-shaped, bony structure called the bony pelvis.

Pepsin (pep'sin) Protein-digesting enzyme secreted by the stomach lining.

Pericardial cavity (per"i-kar'de-al) Space between the parietal and visceral layers of pericardium. Contains a small amount of serous fluid.

Pericardium (per"i-kar'de-um) Double-layered sac that encloses the heart and forms its superficial layer.

Perichondrium (per"i-kon'dre-um) Membrane of fibrous connective tissue that covers the external surface of cartilages.

Perimysium (per"i-mis'e-um) Connective tissue that surrounds and separates fascicles (bundles) of muscle fibers within a skeletal muscle.

Perineum (per"i-ne'um) Region of the trunk superficial to the pelvic diaphragm and bounded by the pubic symphysis anteriorly, coccyx posteriorly, and ischial tuberosities laterally. Contains the anus, vulva (females), and scrotum (males).

Periosteum (per"e-os'te-um) Membrane of fibrous connective tissue that covers the external surface of bones of the skeleton.

Peripheral nervous system (PNS) Portion of the nervous system consisting of nerves and ganglia that lie outside the brain and spinal cord.

Peristalsis (per"i-stal'sis) Progressive, wavelike contractions that squeeze foodstuffs through the alimentary canal (or that move other substances through other body organs).

Peritoneal cavity (per"i-to-ne'al) Space between the parietal and visceral layers of peritoneum. Contains a small amount of serous fluid.

Peritoneum (per"i-to-ne'um) Serous membrane that lines the interior of the abdominopelvic cavity and covers the surfaces of the organs in this cavity.

Peritonitis (per"i-to-ni'tis) Infection and inflammation of the peritoneum.

Peritubular capillaries Capillaries in the kidney that surround the proximal and distal convoluted tubules; active in resorption.

- Phagocytosis** (fag"o-si-to' sis) The process by which a cell forms cytoplasmic extensions to engulf foreign particles, cells, or macro-molecules and then uses lysosomes to digest these substances.
- Pharynx** (far'ingks) Muscular tube extending from the region posterior to the nasal cavity to the esophagus; the "throat" part of the digestive tube.
- Photoreceptors** (fo"to-re-sep'tors) Specialized receptor cells that respond to light energy: rod cells and cone cells.
- Pia mater** (pi'ah ma'ter) Most internal and most delicate of the three membranes (meninges) covering the brain and spinal cord.
- Pinocytosis** (pin"o-si-to' sis) The process by which cells engulf extra-cellular fluids. Also called fluid-phase endocytosis.
- Pituitary gland** (pī-tu'ī-tār'e) A hormone-secreting, golf club-shaped structure that hangs inferiorly from the brain and performs a variety of endocrine functions, such as regulating the gonads, thyroid gland, adrenal cortex, lactation, and water balance. Also called the *hypophysis*.
- Placenta** (plah-sen'tah) Temporary organ formed from both fetal and maternal tissues that provides nutrients and oxygen to the developing fetus, carries away fetal waste molecules, and secretes the hormones of pregnancy; shed as the afterbirth when labor is over.
- Plasma** (plaz'mah) The nonliving, fluid component of blood, within which the blood cells are suspended.
- Plasma cell** Cell formed from the division of an activated B lymphocyte; secretes antibodies.
- Plasma membrane** Membrane that encloses cell contents; the external, limiting membrane of the cell.
- Plasmalemma** (plaz"mah-lem'ah) *See* Plasma membrane.
- Platelet** Cell fragment found in blood; plugs small tears in blood vessels and helps initiate clotting.
- Pleura** (ploo'rah) Serous membrane that lines the pleural cavity in the thorax and covers the external surface of the lung.
- Pleural cavity** (ploo'ral) Space between the parietal and visceral layers of pleura. Contains a small amount of serous fluid.
- Plexus** (plek'sus) A network of converging and diverging nerves or veins.
- Plica** (pli'kah) A fold.
- Podocytes** (pod'o-sīts) Octopus-shaped epithelial cells that surround the glomerular capillaries; they help produce and maintain the basement membrane (a filtration membrane in the kidney).
- Pons** The part of the brain stem between the midbrain and the medulla oblongata.
- Portal system** A system of vessels in which two capillary beds, rather than one, lie between the incoming artery and the outgoing vein of a body region; a portal vein lies between the two capillary beds. Examples are the hepatic portal system and the hypophyseal portal system.
- Posterior** Toward the back; dorsal.
- Posterior lobe of pituitary** *See* neurohypophysis.
- Postganglionic neuron** (gang-gle-on'ik) Autonomic motor neuron that has its cell body in a peripheral ganglion and projects its axon to an effector.
- Preganglionic neuron** (pre"gang-gle-on'ik) Autonomic motor neuron that has its cell body in the central nervous system and projects its axon to a peripheral ganglion.
- Prime mover** Muscle that bears the major responsibility for a particular movement; agonist.
- Process** (1) Prominence or projection; (2) series of actions for a specific purpose; (3) projection from the cell body of a neuron.
- Progesterone** (pro-jes'tě-rōn) Hormone that prepares the uterus to receive the implanting embryo.
- Pronation** (pro-na'shun) Medial rotation of the forearm that causes the palm to face posteriorly.
- Prone** Refers to a body lying horizontally with the face downward.
- Proprioceptor** (pro"pre-o-sep'tor) Receptor that senses movement in the musculoskeletal system; more specifically, proprioceptors sense stretch in muscles, tendons, and joint capsules.
- Protein** (pro'tēn) A long chain of amino acids or several linked chains of amino acids; the amino acid chains have bent and folded (and often coiled) to give each protein a distinct shape.
- Proximal** (prok'sī-mal) Toward the attached end of a limb, or near the origin of a structure.
- Pseudostratified** (soo"do-strat'ī-fīd) Pertaining to an epithelium that appears to be stratified (consisting of more than one layer of cells) but is not; the cells vary in height, but all touch the base of the epithelium.
- Puberty** (pu'ber-te) Period of life when reproductive maturity is reached.
- Pulmonary** (pul'mo-ner"e) Pertaining to the lungs.
- Pulmonary circuit** System of blood vessels that serve gas exchange in the lungs: the pulmonary arteries, capillaries, and veins.
- Pulse** Rhythmic expansion and recoil of arteries resulting from the contraction of the heart; can be felt from outside the body.
- Pupil** Opening in the center of the iris through which light enters the eye.
- Purkinje fibers** (pur-kin'je) Long rows of modified cardiac muscle cells of the conduction system of the heart; also called *subendocardial branches*.
- Pyloric region** (pi-lor'ik) A funnel-shaped region of the stomach, just proximal to the pylorus.
- Pylorus** The distal, ring-shaped portion of the stomach that joins the small intestine and contains the pyloric sphincter muscle.
- Ramus** (ra'mus) Branch of a nerve, artery, or bone.
- Raphe** (ra'fe) A seam in the midline.
- Receptor** (1) Peripheral nerve ending, or complete cell, that responds to particular types of stimulus; (2) a cell component, usually a membrane protein, that binds to specific molecules to signal a certain response.
- Reduction** Restoring broken bone ends or dislocated bones to their original positions.
- Reflex** Automatic response to a stimulus.
- Relay nucleus** Any nucleus in the brain whose neurons receive signals from one region of the central nervous system and relay this information to another region; within the relay nucleus, the information is organized and edited.
- Renal** (re'nal) Pertaining to the kidney.
- Renin** (re'nin) Hormone released by the kidneys that is involved with raising blood pressure, blood volume, and the sodium concentration in blood.
- Respiratory system** Organ system that carries out gas exchange; includes the nose, pharynx, larynx, trachea, bronchi, and lungs.
- Rete** (re'te) A network, often composed of nerve fibers or blood vessels.
- Reticular cell** (rě-tik'u-lar) A fibroblast in reticular connective tissue (in bone marrow, spleen, lymph nodes, and so on).
- Reticular formation** Functional system that runs through the core of the brain stem; involved in alertness, arousal, and sleep; also contains visceral centers that control heart rate, breathing rate, and vomiting; controls some body movements as well.
- Reticulocyte** (rě-tik'u-lo-sīt) Immature or young erythrocyte.
- Retina** (ret'ī-nah) Contains neural layer of the eyeball, including the photoreceptor cells for vision, and a supportive pigmented layer.
- Retroperitoneal** External or posterior to the peritoneum.
- Rhinencephalon** (ri"nen-sef'ah-lon) The part of the cerebrum that receives and integrates olfactory (smell) impulses.
- Ribonucleic acid (RNA)** (ri"bo-nu-kle'ik) Nucleic acid that contains the sugar ribose; acts in protein synthesis.
- Ribosome** (ri'bo-sōm) Cytoplasmic organelle on which proteins are synthesized.
- RICE** An acronym for rest, ice, compression, and elevation; standard treatment for injuries to muscles, tendons, and ligaments.
- Rod cell** One of the two types of photoreceptor cells in the retina of the eye.

Rostral Toward the nasal region or higher brain centers.

Rugae (roo'ge) Elevations or ridges, as in the mucosa of the stomach.

Sacral (sa'kral) Pertaining to the sacrum; the region in the midline of the buttocks.

Sagittal plane (saj'i-tal) A vertical plane that divides the body or a body part into right and left portions.

Sarcolemma (sar'ko-lem'ah) The plasma membrane of a muscle cell.

Sarcomere (sar'ko-mēr) The smallest contractile unit of skeletal and cardiac muscle; the part of a myofibril between two Z discs; contains myofilaments composed mainly of contractile proteins (actin, myosin).

Sarcoplasm (sar'ko-plazm) The cytoplasm of a muscle cell.

Sarcoplasmic reticulum (SR) (sar'ko-plaz-mik rē-tik'u-lum) Specialized smooth endoplasmic reticulum of muscle cells; stores calcium ions.

Sclera (skle'rah) Outer fibrous layer of the eyeball.

Scrotum (skro'tum) The external sac that encloses the testes.

Sebaceous gland (se-ba'shus) Gland in the skin that produces an oily secretion called sebum.

Sebum (se'bum) The oily secretion of sebaceous glands.

Secretion (se-kre'shun) (1) The passage of material formed by a cell to its exterior; (2) cell product that is transported to the exterior of a cell.

Section A cut through the body (or an organ) along a particular plane; a thin slice of tissue prepared for microscopic study.

Semen (se'men) Fluid mixture containing sperm and secretions of the male accessory reproductive glands.

Semilunar valves (sem'i-lu'nar) Valves at the base of the aorta and the pulmonary trunk that prevent blood from returning to the heart ventricles after ventricular contraction.

Seminiferous tubules (sem'i-nif'er-us) Highly convoluted tubules within the testes that form sperm.

Sensory neuron Nerve cell that carries information received from sensory receptors; also called *afferent neuron*.

Serosa (se-ro'sah) *See* Serous membrane.

Serous cell Exocrine gland cell that secretes a watery product containing digestive enzymes.

Serous fluid (se'rus) A clear, watery lubricant secreted by cells of a serous membrane.

Serous membrane Moist, slippery membrane that lines internal body cavities (pleural, pericardial, and peritoneal cavities) and covers visceral organs within these cavities; also called *serosa*.

Serum (se'rum) Amber-colored fluid that exudes from clotted blood plasma as the clot shrinks and then no longer contains clotting factors.

Sinoatrial (SA) node (si'no-a'tre-al) A collection of specialized cardiac muscle cells in the superior wall of the right atrium; pacemaker of the heart.

Sinus (si'nus) (1) Mucous-membrane-lined, air-filled cavity in certain bones of the face; (2) dilated channel for the passage of blood or lymph.

Sinusoid (si'nu-soid) An exceptionally wide, twisted, leaky capillary; large protein molecules or whole blood cells pass easily through the walls of sinusoids.

Skeletal muscle A striated muscle tissue composed of long, cylindrically shaped, multinucleated cells. Located in the muscles that attach to and move the skeleton.

Smooth muscle Musculature consisting of spindle-shaped, unstriated (nonstriated) muscle cells; present in the walls of most visceral organs.

Somatic (so-mat'ik) Pertaining to the region of the body that lies external to the ventral body cavity, including the skin, skeletal muscles, and the skeleton; opposite of *visceral*.

Somite (so'mīt) A mesodermal segment of the body of the embryo.

Special Pertaining to sensory inputs or motor outputs that are *localized* rather than being widespread through the body; opposite of *general*.

Special senses The senses whose receptors are confined to a small region rather than distributed widely through the body: taste, smell, vision, hearing, and equilibrium.

Spermatogenesis (sper'mah-to-jen'e-sis) The process by which sperm (male gametes) form in the testes; involves meiosis.

Sphincter (sfink'ter) A muscle surrounding an opening; acts as a valve to close and open the orifice.

Spinal nerves The 31 pairs of nerves that attach to the spinal cord.

Spinal reflex A reflex mediated through the spinal cord.

Squamous (skwa'mus) Flat, platelike; pertaining to flat epithelial cells that are wider than they are tall.

Stenosis (stē-no'sis) Constriction or narrowing.

Steroids (ste'roids) Group of lipid molecules containing cholesterol and some hormones.

Stimulus (stim'u-lus) An excitant or irritant; a change in the environment that evokes a response.

Striated muscle (stri'āt-ed) Muscle consisting of cross-striated (striped) muscle fibers: skeletal and cardiac muscle.

Stroke Condition in which brain tissue is deprived of its blood supply, as in blockage of a cerebral blood vessel; also called *cerebrovascular accident*.

Stroma (stro'mah) The connective tissue framework of an organ.

Subcutaneous (sub'ku-ta'ne-us) Deep to the skin.

Sulcus (sul'kus) A groove.

Superficial Located close to or on the body surface; outer; external; opposite of *deep*.

Superficial fascia The hypodermis; the fatty layer just below the skin.

Superior Closer to the head; above.

Supination (soo'pī-na'shun) Lateral rotation of the forearm that causes the palm to face anteriorly.

Supine (soo'pīn) Refers to a body lying horizontally with the face upward.

Suprarenal gland (soo'prah-re'nal) *See* Adrenal gland.

Surfactant (ser-fak'tant) Detergent-like fluid secreted by certain cells lining the respiratory alveoli in the lungs; reduces the surface tension of water molecules, thus preventing collapse of the alveoli after each breath.

Suture (soo'cher) An immovable, fibrous joint; except at the jaw joint, all bones of the skull are united by sutures.

Sweat gland Tubular gland in the skin that secretes sweat (which cools the body).

Sympathetic division (sim'pah-thet'ik) Division of the autonomic nervous system that prepares the body to cope with danger or excitement; the fight-or-flight division.

Symphysis (sim'fī-sis) A joint in which the bones are connected by fibrocartilage.

Synapse (sin'aps) Specialized cell junction between two neurons, at which the neurons communicate.

Synaptic cleft Fluid-filled space at a synapse between neurons; also called *synaptic gap*.

Synarthrosis (sin'ar-thro'sis) Any immovable joint.

Synchondrosis (sin'kon-dro'sis) A joint in which bones are united by hyaline cartilage.

Syndesmosis (sin'des-mo'sis) A joint in which bones are united only by a ligament.

Synergist (sin'er-jist) Muscle that aids the action of a prime mover by contributing to the same movement or by stabilizing joints to prevent undesirable movements.

Synovial fluid (sī-no've-al) Fluid secreted by the synovial membranes of the freely movable joints of the body; lubricates the joint surfaces and nourishes the articular cartilages.

Synovial joint Freely movable joint with a cavity and a capsule. *See* Diarthrosis.

Systemic (sis-tem'ik) Pertaining to the whole body.

Systemic circuit System of blood vessels that carries oxygenated blood to the tissues throughout the body.

Systole (sis'to-le) Period during which the ventricles or the atria of the heart contract.

T cells Lymphocytes that mediate cellular immunity; include cytotoxic and helper T cells; also called *T lymphocytes*.

T tubule Extension of the muscle cell plasmalemma (sarcolemma) that protrudes deeply into the muscle cell.

Target cell A cell that is capable of responding to a hormone because it bears receptors to which the hormone can bind.

Taste buds Bulb-shaped sensory organs on and around the tongue that house the receptor cells for taste.

Telencephalon (tel'en-sef'ah-lon) Rostral division of the embryonic forebrain; develops into the cerebrum.

Tendon (ten'don) Cord of dense regular connective tissue that attaches muscle to bone.

Testis (tes'tis) Male primary sex organ that produces sperm; male gonad in the scrotum.

Testosterone (tes-tos'tě-rōn) *See* Androgen.

Thalamus (thal'ah-mus) An egg-shaped mass of gray matter in the diencephalon of the brain; consists of nuclei through which information is relayed to the cerebral cortex.

Thermoreceptor (ther'mo-re-sep'tor) Receptor sensitive to temperature changes.

Thoracic cage Skeletal structures that form the framework of the thorax; includes sternum, ribs, thoracic vertebrae, and costal cartilages.

Thoracic duct Large lymphatic duct that ascends anterior to the vertebral column; drains the lymph from up to three-fourths of the body (all except the body's superior right quarter).

Thorax (tho'raks) That portion of the body superior to the diaphragm and inferior to the neck.

Thymus (thi'mus) Organ of the immune system that is essential for the production of T cells (T lymphocytes); located in the anterior thorax.

Thyroid gland (thi'roid) Butterfly-shaped endocrine gland in the anterior neck; its main hormone (thyroid hormone) increases metabolic rate.

Tight junction A type of cell junction that closes off the intercellular space; also called a *zonula occludens*.

Tissue A group of similar cells (and extracellular material) that perform similar functions; primary tissues of the body are epithelial, connective, muscle, and nervous tissue.

Tissue fluid Watery fluid that, along with the molecules of ground substance, occupies the extracellular matrix of connective tissue; it is a filtrate of the blood containing all the small molecules of blood plasma; also called *interstitial fluid*.

Trabecula (trah-bek'u-lah) (1) Any one of the fibrous bands extending from the capsule to the interior of an organ; (2) a piece of the bony network in spongy bone.

Trachea (tra'ke-ah) Windpipe; the cartilage-reinforced air tube that extends from the larynx to the bronchi.

Tract A collection of nerve fibers in the central nervous system having the same origin, destination, and function.

Transverse process One of a pair of projections that extend laterally from the neural arch of a vertebra.

Trauma (traw'mah) A wound, injury, or shock, usually caused by external forces.

Trochanter (tro-kan'ter) A large, somewhat blunt process on a bone.

Trophoblast (trof'o-blast) External layer of cells in the blastocyst (early embryo); forms the embryo's contribution to the placenta.

Tropic hormone (tro'pik) A hormone that regulates the function of another endocrine organ; tropic hormones signal endocrine glands to secrete their own hormones.

Tubercle (too'ber-k'l) A nodule or small rounded process on a bone.

Tuberosity (too'bě-ros'ĩ-te) A broad process on a bone, larger than a tubercle.

Tumor An abnormal growth of cells; a swelling; a neoplasm; can be cancerous.

Tunica (too'nĩ-kah) A covering or coat; a layer or membrane of tissue.

Tympanic membrane (tim-pan'ik) The eardrum located between the outer and middle ear.

Ulcer (ul'ser) Erosion of the surface of an organ or tissue, such as a peptic ulcer in the wall of the stomach or small intestine.

Umbilical cord (um-bil'ĩ-kal) A cord that attaches to the navel before birth and connects the fetus to the placenta; contains the umbilical arteries and vein.

Umbilicus (um-bil'ĩ-kus) Navel; belly button.

Unipolar neuron (u'nĩ-po'lar) A sensory neuron in which a single short process projects from the cell body but divides like a T into two long processes (central process and peripheral process).

Urea (u-re'ah) The main nitrogen-containing waste excreted in urine.

Ureter (u-re'ter) Tube that carries urine from kidney to bladder.

Urethra (u-re'thrah) Tube that carries urine from the bladder to the exterior.

Uterine tube (u'ter-in) Tube through which the ovum travels to the uterus; also called *fallopian tube* and *oviduct*.

Uterus (u'ter-us) Hollow, thick-walled pelvic organ that receives the developing embryo; site where embryo/fetus develops; the womb.

Varicose vein A dilated vein filled with pooled blood resulting from the failure of the venous valve to prevent backflow in the vessel.

Vasa recta (va'sah rek'tah) Capillary-like blood vessels that supply the loops of Henle and collecting ducts in the medulla of the kidney.

Vasa vasorum Small blood vessels located in the tunica externa of large arteries that supply oxygen and nutrients to the outer layers of the vessel wall.

Vascularized (vas'ku-lar-ĩzd") Having a blood supply; containing blood vessels.

Vasoconstriction (vas'o-kon-strik'shun) Narrowing of blood vessels, normally through the contraction of smooth muscle cells in the vessel walls.

Vasodilation (vas'o-di-la'shun) Relaxation of smooth muscle cells in the walls of blood vessels, causing the vessels to dilate (widen).

Vasomotor fibers (vas'o-mo'tor) Sympathetic nerve fibers that regulate the contraction of smooth muscle in the walls of blood vessels, thereby regulating the diameter of the vessels.

Vein Vessel that carries blood toward the heart.

Ventilation (ven'tĩ-la'shun) Breathing; consists of inspiration and expiration.

Ventral (ven'tral) Toward the front of the body; anterior.

Ventricles (1) Paired, inferiorly located heart chambers that function as the major blood pumps; (2) fluid-filled cavities of the brain.

Venule (ven'ul) A small vein.

Vertebral column (ver'tě-bral) The spine or spinal column; formed of a number of bones called vertebrae, the discs between these vertebrae, and two composite bones (sacrum and coccyx).

Vesicle (ves'ĩ-k'l) A small, liquid-filled sac; also refers to the urinary bladder.

Vesicular follicle (vě-sik'u-lar fol'ĩ-k'l) Mature ovarian follicle; formerly called *Graafian follicle*.

Villus (vil'us) One of many fingerlike projections of the internal surface of the small intestine that together increase the surface area for nutrient absorption.

Viscera (visceral organs) (vis'er-ah) The organs within the ventral body cavity, including the stomach, bladder, heart, lungs, spleen.

Visceral Pertaining to the organs and structures within the ventral body cavity and to all smooth muscle and glands throughout the body; opposite of *somatic*.

Visceral muscle Smooth muscle and cardiac muscle.

Vitamins Organic compounds required by the body in minute amounts that generally must be obtained from the diet.

Vulva (vul'vah) The external genitalia of the female.

White matter White substance of the central nervous system; contains tracts of myelinated nerve fibers.

Yolk sac Embryonic sac that stores a tiny quantity of yolk and gives rise to the lining of the digestive tube; also gives rise to the primordial germ cells and the blood cells.

Zygote (zi'gōt) Fertilized egg.

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WORD ROOTS: PREFIXES, SUFFIXES, AND COMBINING FORMS

Prefixes and Combining Forms

a-, an- *absence, lack* acardia, lack of a heart; anaerobic, in the absence of oxygen
ab- *departing from; away from* abnormal, departing from normal
acou- *hearing* acoustics, the science of sound
acr-, acro- *extreme, extremity; peak* acrodermatitis, inflammation of the skin of the extremities
ad- *to, toward* adorbital, toward the orbit
aden-, adeno- *gland* adeniform, resembling a gland in shape
aero- *air* aerobic respiration, oxygen-requiring metabolism
af- *toward afferent neurons, which carry impulses to the central nervous system*
alb- *white* corpus albicans of the ovary, a white scar tissue
amphi- *on both sides; of both kinds* amphibian, an organism capable of living both in water and on land
ana- *apart, up, again* anaphase of mitosis, when the chromosomes separate
angi- *vessel* angiitis, inflammation of a lymphatic vessel or blood vessel
ant-, anti- *opposed to; preventing, inhibiting* anticoagulant, a substance that prevents blood coagulation
ante- *preceding; before* antecubital, in front of the elbow
ap-, api- *tip, extremity* apex of the heart
append- *hang to* appendicular skeleton
aqua-, aque- *water* aqueous solutions
areola- *open space* areolar connective tissue, a loose connective tissue
arthr-, arthro- *joint* arthropathy, any joint disease
artic- *joint* articular surfaces of bones, the points of connection
atri- *vestibule* atria, upper chambers of the heart
aut-, auto- *self* autogenous, self-generated
ax-, axi-, axo- *axis, axle* axial skeleton, axis of vertebral column
azyg- *unpaired* azygous vein, an unpaired vessel
basal *base* basal lamina of epithelial basement membrane
bi- *two* bicuspid, having two cusps
bio- *life* biology, the study of life and living organisms
blast- *bud, germ* blastocyte, undifferentiated embryonic cell
brachi- *arm* brachial plexus of peripheral nervous system supplies the arm
brev- *short* peroneus brevis, a short leg muscle
broncho- *bronchus* bronchospasm, spasmodic contraction of bronchial muscle
bucco- *cheek* buccolabial, pertaining to the cheek and lip
caput- *head* decapitate, remove the head
carcin- *cancer* carcinogen, a cancer-causing agent
cardi-, cardio- *heart* cardiotoxic, harmful to the heart
carneo- *flesh* trabeculae carneae, ridges of muscle in the ventricles of the heart
caud- *tail* caudal (directional term)

cele- *abdominal* celiac artery
cephal- *head* cephalometer, an instrument for measuring the head
cerebro- *brain, especially the cerebrum* cerebrospinal, pertaining to the brain and spinal cord
cervic-, cervix *neck* cervical vertebrae, vertebrae located in the neck
chondr- *cartilage* chondrogenic, giving rise to cartilage
cili- *small hair* ciliated epithelium
circum- *around* circumnuclear, surrounding the nucleus
clavic- *key* clavicle, a "skeleton key"
co-, con- *together* concentric, common center, together in the center
coel- *hollow* coelom, the ventral body cavity
commis- *united* gray commissure of the spinal cord connects the two columns of gray matter
contra- *against* contraceptive, agent preventing conception
corn-, cornu- *horn* stratum corneum, outer layer of the skin composed of horny cells
corona *crown* coronal suture of the skull
corp- *body* corpse; corpus luteum, hormone-secreting body in the ovary
cort- *bark* cortex, the outer layer of the brain, kidney, adrenal glands, and lymph nodes
cost- *rib* intercostal, between the ribs
crani- *skull* craniotomy, a skull operation
crypt- *hidden* cryptomenorrhea, a condition in which menstrual symptoms are experienced but no external loss of blood occurs
cubit *the elbow* cubital fossa, depression on the anterior side of the elbow
cusps- *pointed* bicuspid and tricuspid, valves of the heart
cyst- *sac, bladder* cystitis, inflammation of the urinary bladder
cyt- *cell* cytology, the study of cells
de- *undoing, reversal, loss, removal* deactivation, becoming inactive
decid- *falling off* deciduous (milk) teeth
delta *triangular* deltoid muscle, roughly triangular in shape
den-, dent- *tooth* dens process of axis, tooth-shaped process
dendr- *tree, branch* dendrites, branches of a neuron
derm- *skin* dermis, deep layer of the skin
di- *twice, double* dimorphism, having two forms
dia- *through, between* diaphragm, the wall through or between two areas
dors- *the back* dorsal; dorsum; dorsiflexion
duc-, duct *lead, draw* ductus deferens, structure that carries sperm from the epididymis into the urethra during ejaculation
dura- *hard* dura mater, tough outer meninx
dys- *difficult, faulty, painful* dyspepsia, disturbed digestion
ec-, ex-, ecto- *out, outside, away from* excrete, to remove materials from the body
ef- *away* efferent nerve fibers, which carry impulses away from the central nervous system
en-, em- *in, inside* encysted, enclosed in a cyst or capsule

endo- *within, inner* endoderm, innermost of the three embryonic layers

entero- *intestine* enterologist, one who specializes in the study of intestinal disorders

epi- *over, above* epidermis, outer layer of skin

erythr- *red* erythrocyte, red blood cell

eu- *well* eesthesia, a normal state of the senses

exo- *outside, outer layer* exophthalmos, an abnormal protrusion of the eye from the orbit

extra- *outside, beyond* extracellular, outside the body cells of an organism

extrins- *from the outside* extrinsic muscles of the tongue

fasci-, fascia- *bundle, band* superficial and deep fascia

fenestra- *window* fenestrated capillaries

fontan- *fountain* fontanelles of the skull

foram- *opening* foramen magnum of the skull

foss- *ditch* mandibular fossa of the skull

gangli- *swelling or knot* dorsal root ganglia of the spinal nerves

gastr- *stomach* gastrin, a hormone that influences gastric acid secretion

germin- *grow* germinal epithelium of the gonads

glosso- *tongue* glossopathy, any disease of the tongue

glute- *buttock* gluteus maximus, largest muscle of the buttock

gon-, gono- *seed, offspring* gonads, the sex organs

hema-, hemato-, hemo- *blood* hematocyst, a cyst containing blood

hemi- *half* hemiglossal, pertaining to one half of the tongue

hepat- *liver* hepatitis, inflammation of the liver

hetero- *different, other* heterosexuality, sexual desire for a person of the opposite sex

hist- *tissue* histology, the study of tissues

holo- *whole* holocrine glands, whose secretions are whole cells

hom-, homo- *same* homeoplasia, formation of tissue similar to normal tissue; homocentric, having the same center

hyal- *clear* hyaline cartilage, which has no visible fibers

hydr-, hydro- *water* dehydration, loss of body water

hyper- *excess* hypertension, excessive tension

hypno- *sleep* hypnosis, a sleeplike state

hypo- *below, deficient* hypodermic, beneath the skin; hypokalemia, deficiency of potassium

hyster-, hystero- *uterus, womb* hysterectomy, removal of the uterus; hysterodynia, pain in the womb

ile- *intestine* ileum, the last portion of the small intestine

im- *not impermeable, not permitting passage, not permeable*

infra- *below, beneath* infraspinatus, the muscle located below the scapular spine

inter- *between* intercellular, between the cells

intra- *within, inside* intracellular, inside the cell

ipsi- *same* ipsilateral, on the same side

iso- *equal, same* isothermal, equal, or same, temperature

jugul- *throat* jugular veins, prominent vessels in the neck

kera- *horn* keratin, the water-repellent protein of the skin

labi-, labri- *lip* labial frenulum, the membrane which joins the lip to the gum

lact- *milk* lactiferous glands, milk-producing glands of the breast

lacun- *space, cavity, lake* lacunae, the spaces occupied by cells of cartilage and bone tissue

lamell- *small plate* concentric lamellae, rings of bone matrix in compact bone

lamina *layer, sheet* basal lamina, part of the epithelial basement membrane

lat- *wide* latissimus dorsi, a broad muscle of the back

later- *side* lateral (directional term)

leuko- *white* leukocyte, white blood cell

lingua- *tongue* lingual tonsil, adjacent to the tongue

lip-, lipo- *fat, lipid* lipophage, a cell that has taken up fat in its cytoplasm

luci- *clear* stratum lucidum, clear layer of the epidermis

lumen *light* lumen, center of a hollow structure

lut- *yellow* corpus luteum, a yellow, hormone-secreting structure in the ovary

lymph *water* lymphatic circulation, return of clear fluid to the bloodstream

macro- *large* macromolecule, large molecule

magn- *large* foramen magnum, largest opening of the skull

mal- *bad, abnormal* malfunction, abnormal functioning of an organ

mamm- *breast* mammary gland, breast

mast- *breast* mastectomy, removal of a mammary gland

medi- *middle* medial (directional term)

medull- *marrow* medulla, the middle portion of the kidney, adrenal gland, and lymph node

mega- *large* megakaryocyte, large precursor cell of platelets

meningo- *membrane* meningitis, inflammation of the membranes of the brain

meso- *middle* mesoderm, middle germ layer

meta- *beyond, between, transition* metatarsus, the part of the foot between the tarsus and the phalanges

metro- *uterus* metroscope, instrument for examining the uterus

micro- *small* microscope, an instrument used to make small objects appear larger

mito- *thread, filament* mitochondria, small, filament-like structures located in cells

mono- *single* monospasm, spasm of a single limb

morpho- *form* morphology, the study of form and structure of organisms

multi- *many* multinuclear, having several nuclei

myelo- *spinal cord, marrow* myeloblasts, cells of the bone marrow

myo- *muscle* myocardium, heart muscle

narco- *numbness* narcotic, a drug producing stupor or numbed sensations

necro- *death* necrosis, tissue death

neo- *new* neoplasm, an abnormal growth

nephro- *kidney* nephritis, inflammation of the kidney

neuro- *nerve* neurophysiology, the physiology of the nervous system

noto- *back* notochord, the embryonic structure that precedes the vertebral column

ob- *before, against* obstruction, impeding or blocking up

oculo- *eye* monocular, pertaining to one eye

odonto- *teeth* orthodontist, one who specializes in proper positioning of the teeth in relation to each other

olfact- *smell* olfactory nerves

oligo- *few* oligodendrocytes, neuroglial cells with few branches

oo- *egg* oocyte, precursor of female gamete

ophthalgo- *eye* ophthalmology, the study of the eyes and related disease

orb- *circular* orbicularis oculi, muscle that encircles the eye

ortho- *straight, direct* orthopedic, correction of deformities of the musculoskeletal system

osteo- *bone* osteoderma, bony formations in the skin

oto- *ear* otoscope, a device for examining the ear

ov-, ovi- *egg* ovum, oviduct

oxy- *oxygen* oxygenation, the saturation of a substance with oxygen

pan- *all, universal* panacea, a cure-all

papill- *nipple* papillary muscles, muscles extending from the wall of the ventricles that anchor the atrioventricular valves

para- *beside, near, beyond* paraphrenitis, inflammation of tissues adjacent to the diaphragm

pariet- *a wall* parietal pleura, the layer of pleura against the thoracic wall

pect-, pectus *breast* pectoralis major, a large chest muscle

pelv- *a basin* pelvic girdle, which cradles the pelvic organs

peni- *a tail* penis, male copulatory organ

pep-, peps-, pept- *digest* pepsin, a digestive enzyme of the stomach; peptic ulcer

peri- *around* perianal, situated around the anus

phago- *eat* phagocyte, a cell that engulfs and digests particles or cells

phleb- *vein* phlebitis, inflammation of the veins

pia *tender* pia mater, delicate inner membrane around the brain and spinal cord

pin-, pino- *drink* pinocytosis, the engulfing of small particles by a cell

pleur- *side, rib* pleural serosa, the membrane that lines the thoracic cavity and covers the lungs

plex-, plexus *net, network* brachial plexus, the network of nerves that supplies the arm

pneumo- *air, wind* pneumothorax, air in the pleural cavity

pod- *foot* podiatry, the treatment of foot disorders

poly- *multiple* polymorphism, multiple forms

post- *after, behind* posterior, places behind (a specific) part

pre-, pro- *before, ahead of* prenatal, before birth

procto- *rectum, anus* proctoscope, an instrument for examining the rectum

pseudo- *false* pseudotumor, a false tumor

psycho- *mind, psyche* psychogram, a chart of personality traits

pulmo- *lung* pulmonary artery, which brings blood to the lungs

pyo- *pus* pyocyst, a cyst that contains pus

quad-, quadr- *four* quadriceps, four muscles located in the anterior thigh

re- *back, again* reinfect

rect- *straight* rectum; rectus abdominis, longitudinal muscle of the anterior abdominal wall

ren- *kidney* renal artery, arterial vessel to the kidney

retro- *backward, behind* retrogression, to move backward in development

ruga- *fold, wrinkle* rugae, the folds in the stomach, gallbladder, and urinary bladder

sagitt- *arrow* sagittal (directional term)

sarco- *flesh* sarcomere, unit of contraction in skeletal muscle

sclero- *hard* sclerodermatitis, inflammatory thickening and hardening of the skin

semi- *half* semicircular, having the form of half a circle

septum *a fence* interventricular septum in the heart

serrat- *saw* serratus anterior, a muscle of the chest wall that has a jagged edge

sin-, sino- *a hollow* sinuses of the skull

soma- *body* somatic nervous system

splanchn- *organ* splanchnic nerve, autonomic supply to abdominal viscera

squam- *scale, flat* squamous epithelium, squamous suture of the skull

steno- *narrow* stenocoriosis, narrowing of the pupil

stroma *spread out* stroma, the connective tissue framework of some organs

sub- *beneath, under* sublingual, beneath the tongue

super- *above, upon* superior, quality or state of being above others or a part

supra- *above, upon* supracondylar, above a condyle

sym-, syn- *together, with* synapse, the region of communication between two neurons

synerg- *work together* synergists, muscles that work together to produce a specific movement

tachy- *rapid* tachycardia, abnormally rapid heartbeat

telo- *the end* telophase, the end of mitosis

templ-, tempo- *time* temporal region of the skull, one of the first locations for hair to become gray, thus showing the passage of time or age

teres *round, smooth* ligamentum teres, also called the round ligament

therm- *heat* thermometer, an instrument used to measure heat

tissue *woven* tissue

tox- *poison* antitoxic, effective against poison

trab- *beam, timber* trabeculae, spicules of bone in spongy bone tissue

trans- *across, through* transpleural, through the pleura

tri- *three* trifurcation, division into three branches

troph- *nourish* trophoblast, from which develops the fetal portion of the placenta

tuber- *swelling* tuberosity, a bump on a bone

vas- *a vessel, duct* vascular system, system of blood vessels

venter, ventr- *abdomen, belly* ventral (directional term)

villus *shaggy hair* microvilli, which have the appearance of hair in light microscopy

viscero- *organ, viscera* visceroinhibitory, inhibiting the movements of the viscera

Suffixes

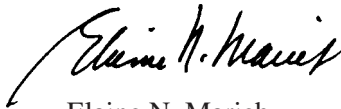
- able** *able to, capable of* viable, ability to live or exist
- ac** *referring to cardiac, referring to the heart*
- algia** *pain in a certain part* neuralgia, pain along the course of a nerve
- ary** *associated with, relating to* coronary, associated with the heart
- ceps** *the head* biceps, a muscle with two heads
- cide** *destroy, kill* germicide, an agent that kills germs
- cipit** *head* occipital
- clast** *break* osteoclast, a cell that dissolves bone matrix
- crine** *secrete* endocrine organs, which secrete hormones into the blood
- ectomy** *cutting out, surgical removal* appendectomy, cutting out of the appendix
- ell, -elle** *small* organelle
- emia** *condition of the blood* anemia, deficiency of red blood cells
- esthesi** *sensation* anesthesia, lack of sensation
- ferent** *carry* efferent nerves, nerves carrying impulses away from the CNS
- form, -forma** *shape* cribriform plate of the ethmoid bone
- fuge** *driving out* vermifuge, a substance that expels worms of the intestine
- gen** *an agent that initiates* pathogen, any agent that produces disease
- glea, -glia** *glue* neuroglia, the connective tissue of the nervous system
- gram** *a record; a recording of data* electrocardiogram, a recording showing action of the heart
- graph** *an instrument recording data or writing* electrocardiograph, an instrument used to make an electrocardiogram
- ia** *condition* insomnia, condition of not being able to sleep
- iatics** *medical specialty* geriatrics, the branch of medicine dealing with diseases associated with old age
- itis** *inflammation* gastritis, inflammation of the stomach
- lemma** *sheath, husk* sarcolemma, the plasma membrane of a muscle cell
- logy** *the study of* pathology, the study of changes in structure and function brought on by disease
- lysis** *loosening or breaking down* hydrolysis, chemical decomposition of a compound into other compounds as a result of taking up water
- malacia** *soft* osteomalacia, a process leading to bone softening
- mania** *obsession, compulsion* erotomania, exaggeration of the sexual passions
- odyn** *pain* coccygodynia, pain in the region of the coccyx
- oid** *like, resembling* cuboid, shaped as a cube
- oma** *tumor* lymphoma, a tumor of the lymphatic tissues
- opia** *defect of the eye* myopia, nearsightedness
- ory** *referring to, of* auditory, referring to hearing
- pathy** *disease* osteopathy, any disease of the bone
- phil, -philo** *like, love* hydrophilic, water-attracting molecules
- phobia** *fear* acrophobia, fear of heights
- plasm** *form, shape* cytoplasm
- plasty** *reconstruction of a part, plastic surgery* rhinoplasty, reconstruction of the nose through surgery
- plegia** *paralysis* paraplegia, paralysis of the lower half of the body or limbs
- rrhagia** *abnormal or excessive discharge* metrorrhagia, uterine hemorrhage
- rrhea** *flow, discharge* diarrhea, abnormal emptying of the bowels
- scope** *instrument used for examination* stethoscope, instrument used to listen to sounds of various parts of the body
- stalsis** *compression* peristalsis, muscular contractions that propel food along the digestive tract
- stasis** *arrest, fixation* hemostasis, arrest of bleeding
- stomy** *establishment of an artificial opening* enterostomy, the formation of an artificial opening into the intestine through the abdominal wall
- tomy** *to cut* appendectomy, surgical removal of the appendix
- ty** *condition of, state* immunity, condition of being resistant to infection or disease
- uria** *urine* polyuria, passage of an excessive amount of urine

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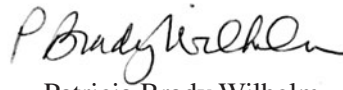
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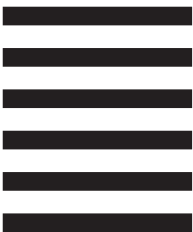
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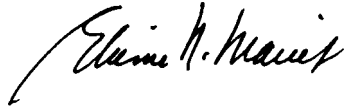
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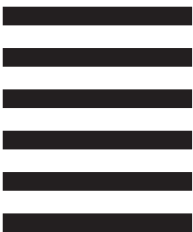
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